SCIENTIFIC AMERICAN
SUPPLEMENT

Fig. 1.—Talaya, Balearic Islands, from Cartailhac.

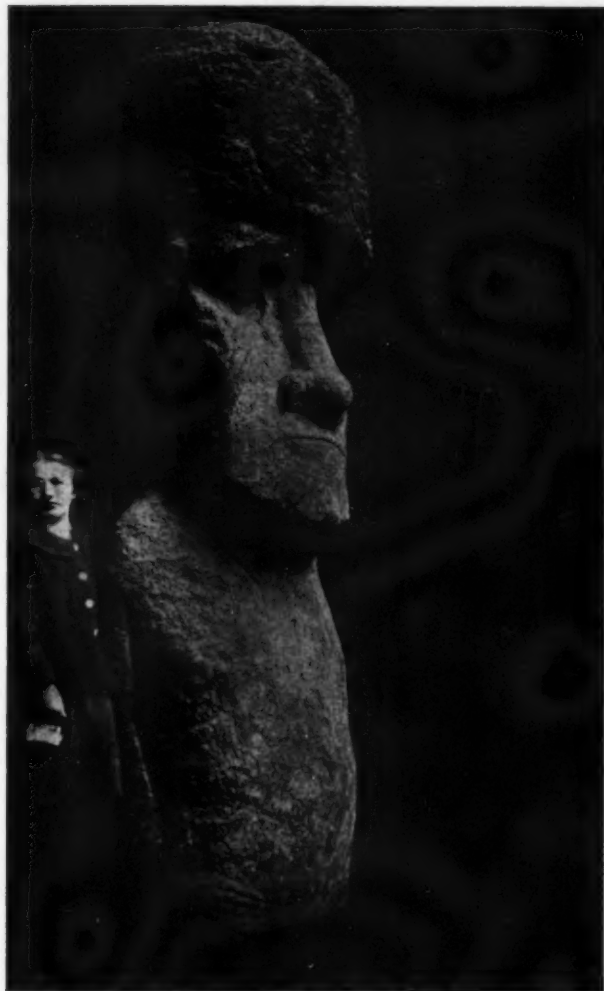Fig. 2.—Corner of massive wall. Cuzco, Peru, from Squier.

Fig. 3.—Stone image from Easter Island, in U. S. National Museum. Photograph by René Bache.

Fig. 4.—Holed-stone, India, from Strand Magazine.

Fig. 5.—Camel colossus, Ming Tombs, China, photograph from F. B. Wright.

Great Stone Monuments
Expressions of Man's Sense of the Higher Powers

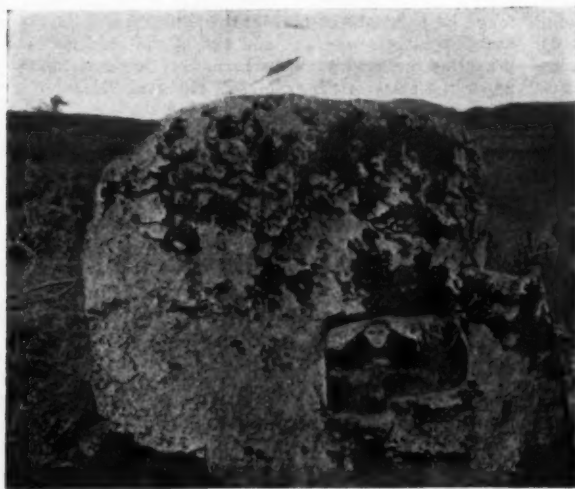Fig. 6.—Stela B. Copan, Honduras, from Maudsley.

Fig. 7.—Holed-stone, Ireland, from Wood-Martin (Welsh's Irish views).

Fig. 8.—Monolith, Abyssinia, from Bent,

STONE MONUMENTS.—[See page 248.]

Syntans[*]

New Artificial Tanning Materials

By Edmund Stiasny

THERE are few branches of chemical industry where the development during the last decades is so striking and where the possibilities and probabilities of further changes are so hopeful as they are in leather industries.

To summarize in a few words the differences between old and present days, the old times can be characterized by handiwork, by a very few tanning materials in use, by slow and uneconomic methods, and finally by a primitive organization of the works. To-day we see the manual work very largely displaced by machine work; we are using a much greater variety of tanning materials, our methods are quicker and more economic, and the organization of the works is far more perfect.

As regards the number of tanning agents used in olden and modern days, the difference is most striking. A few hundred years ago oak bark was *the* tanning material, and sumach was used for light leathers. Of mineral tannins only alum was known, and for fat tannages cod oil was the only material. To-day more than 20 vegetable tannins are used both in the form of the natural materials (bark, wood, fruit, leaves, etc.), and in the form of extracts. Of mineral tanning agents the chromium compounds had a victorious career, and chrome tannage is gaining ground every year. Iron tannage, which was the object of much experimental work done by Knapp in 1858, seems at last to have become a practical process, if one is allowed to believe in the new patents of Von Vietinghoff and Bystron, and the salts of some metals like cerium have also been proposed for tanning purposes. As a mineral tanning agent sulphur must also be mentioned, which not only contributes to the characteristic properties of a two-bath chrome leather, but is also capable of producing a commercial leather when used alone. Besides these, we have formaldehyde and quinone, tanning agents of modern days, which both produce a leather which stands boiling with water, and which both cause the tanning effect, even if very small quantities of the tanning agents are used. That no weight can be expected under such circumstances is obvious, but the white color of the formaldehyde leather, and the beautiful appearance of some formaldehyde-tanned flesh splits shows sufficiently what practical advantages can be expected by this method.

The most important of all is still the vegetable tannage, and it is here that we meet so many unsolved problems, and so little help rendered by science, that the strongly empirical character of this industry seems justified. The three problems yet unsolved are: the chemistry of hide, the chemical constitution of vegetable tannins, and the nature of the vegetable tanning process. As to the chemistry of hide, we are entitled to assume an amphoteric character of the collagen molecule, while the great surface energies of the fibre tissue must not be forgotten, when the possible reactions between hide and tanning agents are discussed. This problem, however, is the same for all kinds of tannages, and need therefor not be specially dealt with here. As to the next problem, the discovery of the chemical constitution of vegetable tannins, we are just on the threshold of a clear understanding of these complex questions, and it is only by the latest work of Emil Fischer, Karl Freudenberg, and their collaborators, that the problem has been solved for gallotannic acid, while the two other substances of understood constitution, viz., ellagic acid and catechin, can scarcely be called tannins, but rather products derived from them. The great bulk of those tannins which are of practical importance to the leather manufacturer are quite unknown to us, as far as their chemical constitution is concerned, and even the sharp analytical distinction between the two classes of tannins (catechol- and pyrogallol-tans) cannot chemically be explained in a satisfactory way. It is obvious, therefore, that questions

of practical bearing like the relation between tanning effect and chemical constitution cannot be answered at all, and it would be of great value if some light were thrown on this darkness.

The practical tanner is well aware that every tanning agent has a characteristic effect of its own on hides and skins, and that the properties of the leather obtained differ widely with the use of different materials. The chemist has only a very few explanations for such differences: he accounts for the weight-giving effect of some pyrogallol tans by the ellagic acid (bloom) which is formed and deposited on and between the fibres, he attributes to the phlobaphenes the filling effect of some catechol tans (hemlock, untreated quebracho, etc.), and he may partially explain the characteristic action of gambier and myrobalans by the presence of catechin, and of chebulinic acid respectively. But these few arguments are quite insufficient to explain the experimental facts, and the differences between the action of chestnut and oak-wood tans, or of quebracho and minosa and of most other tannins, cannot be explained at all scientifically, nor have we even a vague idea of those constitutional reasons which are responsible for the different degrees of astringency. It is this lack of knowledge, and the great difficulties connected with this special branch of research, which cause the empirical character of vegetable tanning. We therefore have to wait until we have got this scientific knowledge before we can proceed in the understanding of the nature of the tanning process itself. This applies to both kinds of general theories of tanning, viz., the purely chemical theory and the adsorption theory. Any conception of tanning as a chemical process (salt formation or condensation process) must start from an exact idea of the chemical constitution of both components, is obvious. But even the adsorption theory necessitates such knowledge, because adsorption is only the first phase of the process, and secondary changes have to follow, which produce insoluble products (by anhydrization, oxidation, and polymerization, etc.), and which cannot be understood without insight into the constitution of the tannin molecule (while the chemistry of the hide is of no importance for th theory).

Considerable time will, however, elapse before the chemical constitution of vegetable tannins will be understood so well that our knowledge of the nature of the tanning process can take advantage of it. But the question arises, is there no other shorter way of studying the problem of the theory of tanning? The following scheme seems to suggest itself. If products can be synthesized which are similar to, if not identical with, vegetable tannin, and which produce a commercial leather, and if the constitution of such synthetic tannins is varied and modified in a controllable way, then the connection between constitution and tanning effect could be studied in a convincing way, and the question could soon be answered, how far the differences in the tannin molecule are responsible for differences in the quality of the leather produced.

Such synthetic tannins may prove to be of direct technical importance, if they can be produced at a reasonable price and if the leather is of sufficiently high quality.

It is such a solution of the problem which has been found lately by the author, by the production of "Syntans" (synthetic tannins), and one of the products is placed on the market by the Badische Company, Ltd., under the name of "Neradol D," the word "Neradol" being registered as a trade mark.

Syntans are condensation products, which can be produced either by heating phenols with formaldehyde in a slightly acid solution and rendering soluble the resinous products thus obtained by means of sulphuric acid; or they can be made by first sulphonating the phenols and then condensing them with formaldehyde under such conditions that only water soluble products are formed.

Though the nature of the condensation process is not exactly studied, it seems very probable that a diphenylmethane derivative is formed which by polymerization leads to molecules of considerable size and consequently to the amorphous character of the product. The syntans resemble in appearance vegetable tanning extracts of bright color; their analogy with natural tans is evident by the following behavior: the aqueous solution of syntans is of a semi-collodial character, it only passes slowly through semi-permeable membranes and gives a precipitate with gelatin. Iron salts produce a deep bluish violet coloration, and a 10 per cent iron alum solution can be used for the control of the course of the Neradol D tannage, by staining the flesh cut of the half tanned hides. Lead acetate and aniline hydrochloride give also precipitation with these syntans.

The most important analogy with vegetable tannins, however, lies in the fact, that Neradol D is capable of converting hide into leather; this has been proved by a great number of experiments both on a small and on a commercial scale, and it seems that there are great possibilities for the application of this tanning agent, both alone and in combination with other materials.

If Neradol D is used alone a soft leather of entirely white color is produced, and this white color, together with considerable toughness of the fibre, form the most characteristic features of this artificial tannage. In using Neradol D alone, one naturally cannot expect to obtain such a variety of tanning effects as one achieves by the great number of different vegetable and mineral tanning agents, and it must be left to the future to find further artificial products by which a similar variety of tanning effects can be obtained as we do now with our present products and methods. There are, however, distinct advantages in using Neradol D in combination with both vegetable and mineral tannins. As regards the heavy leather tannage such a combination may consist in suspending the hides in syntan solutions for a few days and then continuing the vegetable tannage in the ordinary way. Advantages of such combinations are that the grain is tanned gently with syntans, and that such grain is much more resistant against subsequent damages during the tannage; that lime blasts (spots of calcium carbonate which darken in contact with tannin and air) are removed, and the danger of cracking is much diminished in the finished leather. A further advantage is, that the color of the grain remains brighter throughout the following vegetable tannage, because the syntan tannage protects the grain from being darkly colored. If such leather is exposed to light no reddish discoloration takes place as in the case of most vegetable tanned leather, and last, but not least, the speed of the vegetable tannage is considerably increased by such a preliminary treatment with Neradol D, while the weight obtained is at least as good as in the unshortened tannage.

Similar are the advantages in the vegetable tannages of upper and light leather, and special mention may be made of the retanning of East India kips, which after stripping (partial removing of the East Indian tannage) are treated with Neradol D, whereby a leather of very good quality is obtained.

Combinations of Neradol D with chrome tannages have the advantage of bleaching the green color of the chrome tannage, and a very white grain can be produced by a treatment of chrome sole leather before and after impregnating with suitable fats.

It is not necessary to enumerate all the possible ways of using syntans alone or in combination with other tanning materials, and the practical tanner will soon find out his own methods of using the new material.

The experience gained up to now in various leather works justifies the statement that the problem of synthetic tannins has found both a theoretical and a practical solution, and it is to be hoped that the further study of this problem will help to solve the question of the nature of the tanning process itself.

The Port of Galveston

Its Relation to the Industrial and Agricultural Development of the South

By Warren Willsey Peters

GEOGRAPHICALLY, Galveston occupies a strategic position as regards the commerce of the Central West and the Southwest. Its geographical advantages over other ports, and the natural advantage of having a safe harbor, and one that can be deepened or enlarged at slight expense, almost assures its future supremacy as the port of ingress and egress for the Central West and Southwestern States. To commerce, then, the attention of men instrumental in the development of Galveston has been principally directed. From its genesis in 1837 until 1901 Galveston enjoyed a slow, steady growth as the logical port for Texas, Oklahoma,

Kansas, New Mexico and the trans-Mississippi territory. Knocking opportunity was unheard of because of internal troubles arising from a corrupt civic administration, and the adoption of the commission form of government was the beginning of "Modern Galveston."

Galveston is the birth-place of the commission form of government. The city commission is made up of five members—a mayor-president and four commissioners governing particular departments designated as Finance and Revenue, Waterworks and Sewerage, Police and Fire, Streets and Public Property. All power resides in the commission and a majority vote of the body is final. The Mayor is the presiding officer and general director of the affairs of the city, but he has no power beyond his vote as commissioner except some minor abilities to act in case of emergency. The individual commissioners must also come to the board for all power to act. The adoption of the commission form of government has resulted in the construction of a great seawall by the city and county, the raising of the grade of the entire city at a cost of about $4,000,000. An immense causeway, two and one half miles in length, was constructed at an additional cost of $2,000,000. The causeway is one of the largest and most substantial structures of its kind in the world, built with concrete, stone and steel, and converts Galveston Island into a modern peninsula. It provides ample means of ingress and egress for all railroads entering Galveston and for pedestrians and vehicles of all kinds. The city and county are now contemplating an eastward extension of the seawall to encircle the Fort San Jacinto Military Reservation, and this will result in the development of a mile and a half of additional wharf frontage and the reclamation of sixteen hundred acres of land. In February, 1902, the bonded indebtedness of the city was $3,000,000. Since then there has been issued in bonds for permanent improvements, $2,775,000. In the past ten years, under this commission form of government, $1,250,000 of this indebtedness has been retired without the issuance of any refunding bonds, and $1,250,000 has been spent for pavement, drainage, repairs to public buildings and additions to the waterworks system. The tax rate is lower to-day than in any southern city in Galveston's class.

For thirteen years the citizens of Galveston have strained every point for the growth and uplift of the city, until outside capital is now seeking investment within its portals. While the industrial and agricultural development of the South has proven astonishing, commerce has been keeping pace, each year the volume of business handled showing a material increase over the business of the previous year, and a vast majority of this business has been handled through Galveston. Galveston now ranks as the second port in the United States, in the value of its foreign business, and as the largest cotton exporting port in the world, and because of its wonderfully interesting engineering accomplishments it has been closely watched by the civilized world. The permanence of the city having been established beyond question, its commercial interests began to increase. While nearly every commodity shipped from the Southwest is exported through Galveston, cotton is naturally the leading export, the territory tributary to Galveston being the cotton raising center of the world. The following table shows the cotton crop of the United States and the amount of the staple exported through Galveston during the past twelve years:

Year.	United States Crop. Bales.	Exported Through Galveston. Bales.
1912	16,043,316	4,294,290
1911	12,132,332	3,002,961
1910	10,650,961	2,436,429
1909	13,828,846	2,563,168
1908	11,581,829	3,154,429
1907	13,550,760	2,727,507
1906	11,319,860	2,688,157
1905	11,319,860	2,388,157
1904	10,123,686	1,883,412
1903	10,758,326	2,070,098
1902	10,701,453	1,742,142
1901	10,425,141	1,961,389
Totals	144,673,351	30,906,139

More than one fifth of the entire cotton crop of the United States for twelve years has been exported through Galveston to the important marts of the world. The above table includes only foreign business and vast amounts of the staple have been carried to New York by coastwise steamship lines. These figures faithfully present the development and growth of Galveston's cotton industry. The calendar year of 1912 broke all records in the movement of cotton through this port.

The record for the fiscal year ending August 31, 1913, passed the 5,000,000 bale mark. Notice in the foregoing table the growth of the crop during the last two years, indicating increased acreage planted with cotton. Increased crops are becoming the rule, resulting in increased exports. A similar ratio of increase accrues to corn, wheat, cotton seed meal and cake, provisions, lumber, iron and steel. The greatly increasing number of steamships, locomotives and stationary engines using mineral oils for fuels, has resulted in the exports of this particular commodity being a feature of the recent business over the Galveston wharves. During the last twelve months the exports of fuel oil reached in value $150,000.

The rapid industrial and agricultural development of the South is not mysterious when "Galveston" is used as the key-word. Review the situation briefly. Smith Center, in Kansas, is accredited to be the geographical center of the United States, is in the heart of the grain section, is 1,290 miles from San Francisco, 1,335 miles from New York, 1,210 miles from Baltimore, but only 770 miles from Galveston. Galveston is from 500 to 600 miles nearer the grain section and holds the advantage of an almost level haul from producing territory to tidewater, slightly downgrade all the way. Contrast this with the hauls over the Alleghany Mountains to New York or Baltimore, or the Rockies to San Francisco. A logical conclusion is that the products of farm and forest will be shipped the shortest and least expensive way to the port whose natural water facilities are unexcelled. Where the railroads enjoy increased business a rapid and steady development of the country is certain to accrue, and this section of the South owes its development largely to the increase of commercial facilities at Galveston. Nothing better reflects the true conditions than the number of cars handled during the year over the terminal lines operating at Galveston. 181,122 cars were received and unloaded at Galveston during 1912, an increase of 34,339 cars over the record for 1911. Another increase for 1913 is now indicated. Based on an average length of 30 feet these cars would reach from Galveston to Cincinnati, a distance of 1,045½ miles.

Increasing marine tonnage eloquently sets forth the commercial growth of Galveston, which is essential in keeping pace with the development of the South and the great Southwest. Twelve years ago thirty steamship lines touched at Galveston, the record showing that 347 ships, with a gross tonnage of 786,100 tons, cleared, and 291 ships, with a gross tonnage of 645,044 tons, entered. In twelve years the number of steamship lines entering Galveston increased more than double and at present sixty-four lines of steamships ply between this port and the other great ports of the world. The following table shows the actual increase for the past twelve years:

Year.	Ent'd.	Tons.	Year.	Cleared.	Tons.
1912	553	1,369,296	1912	701	1,815,031
1911	358	910,111	1911	489	1,262,784
1910	276	687,058	1910	425	1,078,700
1909	282	893,770	1909	424	1,114,963
1908	464	1,139,915	1908	599	1,443,207
1907	413	1,009,317	1907	533	1,268,297
1906	419	952,302	1906	552	1,200,275
1905	372	733,456	1905	507	1,082,244
1904	305	567,160	1904	399	842,194
1903	305	679,968	1903	385	950,327
1902	205	579,917	1902	300	922,319
1901	200	645,044	1901	347	786,100

The disparity shown between the gross tonnage for various years is attributed largely to the fluctuation of crops. There is indicated, with normal crop conditions, a gradual development and increased acreage throughout the Central West and the Great Southwest. The 1913 crop promises to be the greatest on record and the tonnage will doubtless be greatly increased. Four grain elevators, with a capacity of 5,000,000 bushels, and facilities for loading grain ships at the rate of more than 150,000 bushels per hour is what enables Galveston to cope with the rapid development of the grain industry, while warehouse rooms and wharf facilities for 500,000 bales of cotton is beginning to prove inadequate. Two immense cotton concentration sheds and compressing plants covering one hundred acres of ground are now being erected to meet the growing demand for room and improved facilities.

The industrial and agricultural development of the South is further reflected in the increase of Galveston's bank clearings. Last year's bank clearings were $1,000,858,000 an increase of $123,025,000 over the clearings of the previous year. The expending of several millions of dollars in deepening the principal harbors in Cuba will doubtless result in an increased trade for Galveston and hence in an increased industrial and agricultural development for the South. Another contributing feature will be the Intercoastal Canal, two hundred miles of which were completed and opened in June, connecting Galveston with about eight hundred miles of navigable waterways in the Texas coast country. The Canal will ultimately reach the Mississippi to the Rio Grande and will connect Galveston by a protected inland waterway with every port and hundreds of river and bayou towns on the Louisiana and Texas coast, providing outlets to many sections now almost devoid of communication. The territory to be served by this water-way is very fertile and already occupies a prominent place among the agricultural sections of the two states, and much cotton, rice and other products will move over it when completed. The section of the canal opened recently gives promise of becoming one of the important trade arteries of Texas, connecting Galveston, as it does, with all of the coast country westward as far as Corpus Christi.

In its relation to the Panama Canal and the Latin-American republics, Galveston stands pre-eminently as the logical point for shipments to and from the central portions of the country. Survey, northward to Winnepeg, the cities and states, their population and their industries, from the Mississippi to the Rockies; all that vast region must henceforth pay tribute to the port of Galveston, because from any point about Smith Center, Kansas, or north of it, the nearest port is Galveston,—500 miles nearer than any route across the Rockies to San Francisco, or any line eastward via the Alleghanies to Baltimore or New York. Compare then the distance southward from these ports to the Panama Canal, and figure on the actual and possible trade developments of the west coast of South America as far Southward as Valparaiso, which is 2,659 miles from Panama. From Galveston to Colon (Panama), 1,485 miles; from New York to Colon, 2,312 miles; from San Francisco to Panama, 3,875 miles. Galveston is by steamer 827 miles nearer the canal than is New York, and 2,390 miles nearer than is San Francisco. In shipments of flour and lumber, Galveston holds the key, almost exclusively so, for the cotton markets in Japan. Already Japanese steamship lines are preparing for the handling of cotton from Galveston, thence through the canal, thus saving a trans-continental to the ports of the Pacific.

Galveston is well equipped to handle the trade that passes through its gates. It has extensive wharf facilities, possessing in the aggregate more than fifteen miles of available slips for ocean-going vessels, including the wharves of the Galveston Wharf Company and the Southern Pacific Company. The harbor terminals are capable of berthing more than 100 large steamships at one time, and their value exceeds $20,000,000. The Federal Government has already expended more than $15,000,000 on harbor improvements and there is now available a deep water channel from the Gulf of Mexico to the docks at Galveston having a minimum depth of thirty feet all the way. Further improvements by the Government to the extent of $20,000,000 are now contemplated. For the future there is available two hundred miles of water frontage on Galveston Bay capable through development under the slip system of making more than one thousand miles of dock frontage. Citizens confidently believe that all available space will some day be required to meet the trade demands from the immense territory directly and indirectly tributary to Galveston, the area in Texas alone, cultivated and capable of cultivation, being larger than Germany and the British Isles combined. The climate of Galveston is exceptionally even. The Gulf Stream flowing by the city preserves an even temperature throughout the year. While located farther south than any other city of its size in the United States, the summer temperature is unusually low, the average maximum for the months of July and August for the past ten years being a little in excess of 88 degrees, while frost in the winter is a rarity.

And to the industrial and agricultural development of the South these facts mean much. The great trunk lines of railroads participating in the haul of southward moving commodities must continually improve facilities, must enlarge yards, build new shops, must grow with the growing trade. Growing railroads means growing cities and towns, and brings people into the agricultural districts who develope hitherto unfruitful, yet fertile lands. With more than one quarter of the country's area paying tribute to the Port of Galveston, the continued industrial and agricultural development of that section of the South directly tributary to Galveston seems assured.

Peat Powder as a Locomotive Fuel

PEAT powder has been successfully applied as a locomotive fuel on one of the private railroads in Sweden. About 1½ tons of peat powder is equivalent in steam rising value to one ton of coal. Peat powder is used with a mixture of about 5 per cent of coal. The powder is fed into the furnace by an automatic stoker. No change need be made in the boiler and in the fire-box, except for the mounting and application of the automatic stoker. An incidental advantage of the use of the peat powder is that no cold air can get into the fire-box and no smoke or sparks escape from the smoke-stack. As Sweden is very rich in peat bogs and has practically no coal deposits the success of the apparatus, which has been worked upon for years by eminent engineers, is of considerable importance. It has been estimated that the cost of peat powder would be only about one half that of coal.—*Machinery.*
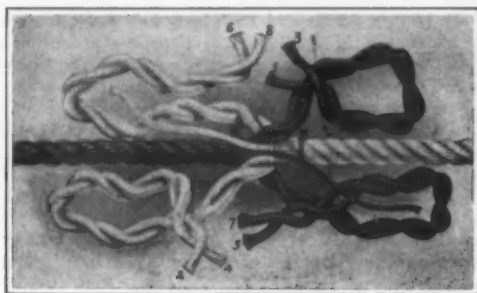
Fig. 1.

WE have had occasion in a previous issue to set forth some of the advantages of rope transmission. So far as the use of ropes for power transmission has led to complaints, it may be said that most of the "troubles" complained of in rope drives are directly caused by bad splicing, although it is a simple matter to make a proper splice, once the idea has been grasped.

The essential points in a transmission splice are: First, that its diameter be absolutely the same as that of the original rope; second, that it be smooth and free from lumps; third, that the original lay of strands and yarns be disturbed as little as possible; and fourth, that where the several strands are rejoined, each fastening or "tuck" should be made in such manner as to prevent its wearing away and the rope unstranding.

There are many different splices now in use, but after a careful study of each we are convinced that all the above features are combined only in what is called the English transmission splice, and experience has proved it the best one known.

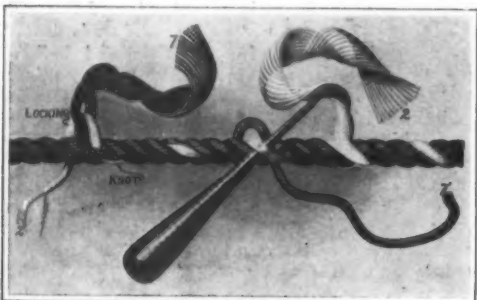* By courtesy of the American Manufacturing Company.

Fig. 4.

Fig. 6.

Fig. 2.

Splicing Transmission Rope*

A Correctly Made Splice Is Essential to Satisfactory Service

In describing this we take for our example a four-strand rope, 1¾ inches diameter, as spliced on sheaves in the multiple system.

The rope is first placed around sheaves, and, with a tackle, stretched and hauled taut; the ends should pass each other from six to seven feet, the passing point being marked with twine on each rope. The rope is then slipped from sheaves and allowed to rest on shafts, to give sufficient slack for making splice.

Unlay the strands in pairs as far back as the twines, M M¹, crotch the four pairs of strands thus opened (Fig. 1), cores having been drawn out together on the upper side.

Then, having removed marking twine M, unlay the two strands 6 and 8, still in pairs, back a distance of two feet, to A; the strands 1 and 3, also in pairs, being carefully laid in their place.

Next unlay the strands 5 and 7 in pairs, to A¹, replacing them as before with 2 and 4. The rope is now as shown in Fig. 3.

The pair of strands 6 and 8 are now separated, and 8 unlaid four feet back, to B, a distance of six feet from center, strand 6 being left at A. (See Fig. 2.)

The pair of strands 1 and 3 having been separated, 3 is left at A, as companion for 6, strand 1 being carefully laid in place of strand 8 until they meet at point B.

The two pairs of strands 2-4 and 5-7 are now separated and laid in the same manner, every care being taken, while thus putting the rope together, that original twist and lay of strand are maintained.

The protruding cores are now cut off so that the ends, when pushed back in rope, butt together.

The rope now appears as shown in Fig. 2, and after the eight strands have been cut to convenient working lengths (about two feet), the companion strands are ready to be fastened together and "tucked."

This operation is described for strands 2 and 7, the method being identical for the other three pairs.

Unlay 2 and 7 for about 12 to 14 inches, divide each strand in half by removing its cover yarns (see Fig 4), whip with twine the ends of interior yarns 2' and 7';
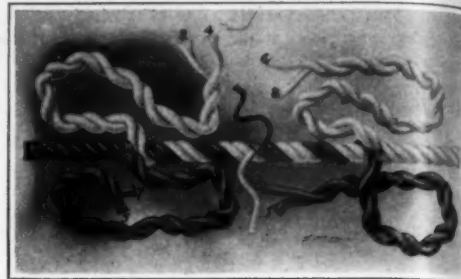
then, leaving cover 2, relay 2' until near 7 and 7', here join with simple knot 2' and 7' (Fig. 5).

Divide cover yarns 7, and pass 2' through them, continuing on through the rope *under* the two adjacent strands, avoiding the core, thus locking 2' (Fig. 6). *In no event pass 2' over these or any other strands.*

Half strand 7' must now be taken care of; at the right of the knot made with 2' and 7', 2' is slightly raised with a marlin spike, and 7' passed or tucked around it two or three times, these two half strands forming in this way a whole strand. Half-strand 7 is tucked until cover two is reached, whose yarns are divided and 7' passed through them and drawn under the two adjacent strands, forming again the lock. The strand ends at both locks are now cut off, leaving about two inches, so that the yarns may draw slightly without unlocking. This completes the joining of one pair of strands (Fig. 7). The three remaining pairs of strands are joined in the same manner.

After the rope has been in service a few days, the projecting ends at locks wear away, and if tucks have been made carefully, and original twist of yarns preserved, the diameter of the rope will not be increased, nor can the splice be located when rope is in motion.
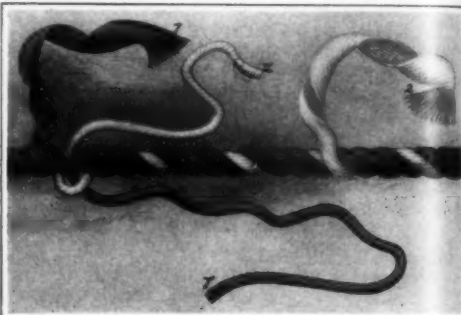

Fig. 5.

Fig. 3.

Fig. 7.

The Manufacture of Hydrogen from Water Gas*

The Separation is effected at —205° C., the lowest temperature reached in any industrial process

By Henri Brot

THE use of very low temperatures has not only furnished us with a valuable industrial process for the production of oxygen and nitrogen from the atmosphere, but has also given us an economical method of manufacturing hydrogen.

In the manufacture of nitrogen and oxygen from air, either of two general methods may be made use of:

1. Either the air is liquefied and is then subjected to a fractional distillation (rectification). This is the basis of the Linde process.

2. Or the air is subjected to partial liquefaction; the oxygen, being less volatile, is the principal product of condensation. The residual gas is then liquefied and fractionally distilled. This is the method followed in the Claude process.

Hydrogen also can be very economically prepared by the use of very low temperatures by a somewhat similar process, due to Messrs. Linde, Frank and Caro. This process has gained special interest owing to the

* Translated for the SCIENTIFIC AMERICAN SUPPLEMENT, from Le Génie Civil.

fact that of late hydrogen has found increasing application for aeronautical purposes, for the production of synthetic ammonia (see this SUPPLEMENT, July 26th, 1913, page 58), for the hydrogenation of oils to produce therefrom solid fats (see this SUPPLEMENT February 1st, 1913, page 71), etc. On the other hand, a description of this process is of peculiar interest owing to the very considerable technical difficulties which had to be overcome in developing it. As will be seen, the temperatures employed in the processes for the manufacture of oxygen and nitrogen from air are not sufficiently low to effect the separation of hydrogen from water gas, and to achieve this result new apparatus had to be devised. The temperature employed is no less than 205 deg. Cent. below the freezing point of water, and is the lowest temperature reached in any industrial manufacturing process.

PRINCIPLES OF THE LINDE, FRANK AND CARO PROCESS.

Water gas consists essentially of hydrogen, carbon monoxide and nitrogen. It also contains a comparatively small percentage of carbon dioxide. The proportion

in which the several ingredients are present depends on the temperature at which the gas was prepared. In the Linde, Frank and Caro process the raw material employed consists of water gas containing about 50 per cent of hydrogen. The first step is to eliminate the carbon dioxide by passing the gas over caustic potash. The gas thus purified is then compressed to about 30 atmospheres and cooled to a temperature in the neighborhood of the normal boiling point of oxygen, say 200 degrees Cent. A partial liquefaction takes place, and two phases are formed, the one liquid, containing a higher percentage of liquefiable constituents than the original gas mixture; the other gaseous, and containing a higher percentage of volatile constituents than the original mixture.

The volatile constituent of the mixture is the hydrogen, whose critical point is —242 degrees Centigrade. The liquefiable constituents are the carbon monoxide and nitrogen, whose critical temperatures are respectively —136 degrees Centigrade and —146 degrees Centigrade. The conditions of pressure and temperature selected

are such that the liquid phase, very rich in carbon monoxide, contains but little hydrogen, and the gaseous phase rich in hydrogen, contains very little of the other constituents, only about 2.5 to 3 per cent.

GENERAL DESCRIPTION OF THE PLANT.

Prof. Linde's method, as employed in the preparation of liquid air, can not be used for the liquefaction of water gas.

This method, as is well known, consists in first compressing the gas, thereby raising its temperature; thereupon cooling it to the temperature of the surroundings; and finally extracting from the gas the heat corresponding to internal work of expansion, by allowing it to escape through a valve (Joule-Thomson effect).

The water gas employed contains, as has been stated, 50 per cent of hydrogen, and therefore on the whole displays the physical properties of hydrogen. Now, it will be remembered that hydrogen presents a peculiarity, as compared with other gases (except helium, which in this respect resembles hydrogen), in that the product $p\,v$ (pressure times volume) increases with the pressure, instead of decreasing as the pressure increases, as is the case with air for example. (See the curves, Fig. 1.)

On the other hand, the temperature change produced by the Joule-Thomson effect is given by the relation:

$(T_1-T_2)C_v = (r_1-r_2) + A(p_2v_2-p_1v_1)$ where T is the temperature, p the pressure, v the volume and r internal energy. The suffix 1 denotes the value of the corresponding variable before expansion, and the suffix 2 similarly relates to values after expansion. The symbol C_v denotes as customary the specific heat at constant volume, while A is the factor by which the number of work units measuring a given quantity of energy is converted into the corresponding number of heat units. The curve shown in Fig. 2 rises sufficiently steeply to cause the term $A(p_2v_2-p_1v_1)$ to exceed (in absolute value) the term (r_1-r_2). Hence T_1-T_2 is negative, or in other words, T_2, the temperature after

Fig. 1.—Diagrammatic general view of a plant for manufacturing hydrogen.

expansion, is greater than T_1, the temperature before expansion.

Hence, when allowed to escape from an open valve, at the temperature of the surroundings, hydrogen does not cool, but on the contrary, rises in temperature.

Thus the Linde method, as applied in the liquefaction of air, is not applicable for cooling water gas, and another expedient must be resorted to, as in the liquefaction of hydrogen. The agent made use of is liquid air. By allowing it to evaporate it can be made to furnish the requisite degree of cold to reach the temperatures in question.

COLD-ECONOMIZER PRINCIPLE.

In spite of the high price of "cold" (one frigorie between —10 and —15 deg. Cent. costs from twelve to fifteen times as much as one calorie), the constituents of the air are produced by liquefaction industrially at a very low figure, owing to the fact that the cold employed in the process is "recovered" after the manner of "heat recovery" in a heat exchanger. In fact, in the Linde oxygen and nitrogen process cold is merely a means to an end. The purpose is not to produce cold, but simply to furnish a temperature at which the two gases can be separated. The products themselves, oxygen and nitrogen, or hydrogen and carbon monoxide, as the case may be, are of course not collected at this low temperature, but at that of the room. Hence both the cold of the liquid carbon monoxide and that of the gaseous products is conserved in the apparatus.

COLD OF THE LIQUID CARBON MONOXIDE.

As the liquid carbon monoxide issuing from the process is vaporized, the heat necessary for this evaporation is imparted to it by the entering stream of carbon monoxide, which, in assuming the liquid form, absorbs the cold contained in the previously liquefied carbon monoxide, according to the well-known counter-current principle.

This corresponds exactly to what would occur if the problem were to liquify water vapor, (steam) at 100 degrees Centigrade, if the only source of cold (refrig-

erator) at our disposal were water also at 100 degrees Cent. which was to be evaporated. Evidently all that would be required would be to cause the steam to pass through a worm tube immersed in the hot water. The liquifaction would take place within this tube

Fig. 2.—Curves showing the variations in the product "pv" of different gases as functions of the pressure of "p" at different temperatures.

with the liberation of heat, while at the same time, in the hot water jacket around the worm tube evaporation would occur with absorption of heat and the quantities liquefied and vaporized would be almost equal. We note that it would be necessary for the steam to be slightly compressed, so that it would become liquefied at a temperature just a little above that of the water, for in order that heat should pass from one surface of the worm tube to the other, there must be at least a slight temperature difference provided.

COLD OF THE GASES.

In the same way the cold gases, after separation, pass through heat exchangers in which they become reheated while themselves absorbing heat from the entering stream of gas.

These heat exchangers are constructed, as in all Linde apparatus, of concentric tubes. The gases circulate either through the central bore of the tubes or through the annular outer channel, and the heat exchange takes place through the walls of the tubes. For the sake of compactness the tubes are coiled up into spirals or worms. Proper care is of course taken to provide as perfect a heat insulation as possible, so as to prevent heat losses (or to be more exact, losses of cold) by heat conduction and radiation.

It would seem at first sight as if the net balance of heat produced and consumed in apparatus per unit of time were zero, and as if, once the apparatus were started, there were no further need of producing any cold. Under these circumstances the preparation of the gases should consume no other energy than that small amount which is necessary to keep the gases flowing through the apparatus.

But, as in all industrial operations, there is of course a certain loss, and the heat balance is not zero for the following reasons:

1. To cause the separation of two gases, even if purely physically mixed, theoretically requires a certain amount of work to be done, so that a fortiori in practice such work must actually be furnished.

2 However well designed and constructed the apparatus may be it is not perfect and there are certain losses of cold which occur.

Fig. 3.—Diagram of apparatus for manufacturing hydrogen from water gas by the aid of liquid air according to the process of Linde, Frank and Caro.

ENERGY ABSORBED IN THE SEPARATION OF A PHYSICAL MIXTURE OF TWO GASES.

The purely physical separation of two gases which are mechanically mixed together requires the expenditure of a certain amount of work. A simple proof of this fact has been given by Mr. G. Claude, who has taken his clue from the work of Van der Waals. Let a mixture of two gases be placed in a cylinder in the bore of which two pistons can be moved, of which one is perfectly permeable to carbon monoxide, but impermeable to hydrogen, while the other on the contrary allows hydrogen to pass unhindered while being completely impermeable to carbon monoxide. Suppose that one piston is placed at each extremity of the cylinder, which is filled with the gas mixture at atmospheric pressure. Then let the two pistons be brought together until they touch, the distance traveled by each being proportional to the percentage of the particular gas to which it is permeable. We shall then have the two gases separated and contained respectively in the two spaces comprised between the walls of the tube and the pistons. The gases will moreover be at atmospheric pressure. It will be seen that the minimum work required thus to separate the gases will be the sum of the work of isothermal compression of each gas from its partial pressure in the original mixture to atmospheric pressure. It is therefore impossible by any method to separate two gases without expending work.

Fig. 4.—Diagrammatic plan view of a plant for manufacturing hydrogen

a, steam boiler; b, gas purifier; c, gas generator; d, ventilator; e, gasometer for water gas; f, gasometer for carbon monoxide; g, gas engine; h, air compressor; j, ammonia compressor. For the sake of simplicity only the conduits conveying the water gas, the carbon monoxide and the hydrogen have been shown.

The question arises, where, in the course of the process with which we are concerned, do we find the equivalent of this expenditure of energy. Mr. Claude is of the opinion that the item in question appears in the necessity of compressing the gases before treatment. Is this correct? At first sight it seems not to be so, for since we are now considering the matter from a purely theoretical point of view, we are justified in considering the wall of the worm tube as having an infinite conductivity. In this case the difference of temperature between its two faces may be made as small as desired, no matter how great the heat transfer through the tube. But it must not be forgotten that on the outside of the worm tube we have liquid carbon monoxide, and on the inside a gaseous mixture, and that it is necessary to establish the requisite conditions to ensure effective separation.

To do this it is necessary to compress the gases to be treated and there can be no doubt that it is at this point in the process that the expenditure of energy required to effect separation enters into the process.

IMPERFECTIONS OF THE APPARATUS.

However carefully constructed and designed the heat exchangers may be, they are not perfect, and the gases which issue from the apparatus are in practice always of a temperature several degrees below that of the entering gases. Again, however carefully insulated the apparatus may be, the heat conductivity of their insulating mantles is never quite zero, so that there is always a slight loss of cold which must be made good. In order to compensate for these losses, liquid air is continuously supplied to the apparatus after once operations are started, which, by its evaporation, furnishes the requisite amount of cold.

GENERAL DESCRIPTION OF THE APPARATUS.

The apparatus employed is diagrammatically represented in Fig. 3 of our drawings. A is the heat exchanger with the three conduits a, b, c, which convey respectively the compressed water gas, the hydrogen, and the carbon monoxide and nitrogen. B is the vaporizer. Within the worm tube, the liquefiable constituents of the gas mixtures are condensed, while in the space around this coil, the carbon monoxide introduced

through valve C is vaporized, after having been separated in the separator D. E is a valve at which the hydrogen may be allowed to expand, before it is drawn from the apparatus. Finally, F represents diagrammatically the liquid air jacket which serves on the one hand for the preliminary cooling and on the other for the continued cooling during the process for the purpose of making good incidental losses.

Hydrogen prepared in this manner is not absolutely pure; as has been stated above, it contains about 2.5 to 3 per cent of impurities. Nevertheless this is a very creditable performance, as will be well understood by those who are familiar with the industrial manufacture of gases, and who know the difficulties of obtaining the last degrees of purity in the product.[1] This degree of purity is sufficient for most uses. Nevertheless in certain cases, especially for aeronautics, where density is a very important factor, it is desirable to increase as far as possible the hydrogen contents. A percent of 97 to 97.5 hydrogen corresponds to a density of 0.094, while when the percentage of hydrogen is raised to 99.2 or 99.4 percent, the density falls to 0.077. The lifting power of one cubic meter of the gas is then raised from 1,175 to 1,195 grams.

A gas containing a very high percentage of hydrogen can be obtained by passing the 97 per cent over gas soda lime. This yields a product containing as its only impurity 0.6 to 0.8 percent of nitrogen.

The accompanying illustrations Figs. 1 and 4, which are derived from the *Zeitschrift des Vereins, Deutscher Ingenieure* and the *Zeitschrift für Angewandte Chemie* give a rather more complete representation of the entire plant. In Fig. 1 A is a compound compressor for compressing the water gas. This gas contains about three percent of carbon dioxide, which must first be eliminated,

[1] It is interesting to note here that the manufacture of cyanamide calls for the use of nitrogen of 99.8 per cent purity. The apparatus devised by Linde and Claude completely fulfills these requirements.

since it would become solid in the course of the process and stop up the pipes. Hence, after the first stage of the compression, the gas mixture is passed through purifying towers B, in which a current of water absorbs the greater part of the carbon dioxide Then, after issuing from the compressor, the stream of gas is passed over caustic potash contained in receptacle C, which arrests the last traces of carbon dioxide and also takes up any moisture present, which would of course cause the same trouble as that just pointed out with regard to carbon dioxide. D and E are the usual coolers for the compressor. F is the separating apparatus described above. G is the liquid air plant worked by the aid of liquid ammonia in the usual way. L is the soda lime purifier for the hydrogen.

Fig. 4 is a plan view in which the reference letters denote the same features as in Fig. 1. In spite of the preliminary purification of the water gas, whereby water vapor and carbon dioxide are eliminated, traces of these bodies nevertheless pass into the separating apparatus, and, being deposited there in the solid form, ultimately obstruct it after the lapse of a certain time. This inevitable though regrettable condition is met by using two similar apparatus employed in rotation, say in weekly shifts. Whichever of the duplicate plants is out of operation can in the meantime be brought back into working shape by heating it and blowing gas through it.

BY-PRODUCTS OF THE HYDROGEN MANUFACTURE.

In this process of manufacture the principal product is of course the hydrogen; nevertheless it is possible to recover certain by-products which are not without value. Thus the carbon monoxide can be collected in a gasometer in quantities sufficient to feed a gas motor which can be used to drive the compressors of the plant.

Moreover we noted above that the cold lost by conduction, etc., must be made up for by a cold furnished from evaporating liquid air. Prof. Linde has succeeded in recovering separately oxygen and nitrogen as by-

products from this step of the process.

The carbon monoxide could be rectified and obtained pure. But hitherto it has been found more satisfactory to simply employ it as a fuel without preliminary purification.

COST OF PRODUCTION.

In figuring out the cost of production with reference to a plant which produces only hydrogen, we have the following items:

Hourly production in cubic meters of hydrogen	50	100	200	500
Water gas consumed cubic meters per hour	125	250	500	1250
Coke consumed per hour (lbs.)	176	352	704	1720
Cooling water required cubic meters per hour	3.8	7.6	13.5	32.5

From these data it will be seen that for plants of the type considered, the consumption of materials is very nearly in proportion to the output. This is due to the fact that the percentage composition of the gaseous products is practically independent of the size of the apparatus. Nevertheless the advantages of large scale apparatus is felt in a reduction in the proportionate consumption of coke and cooling water. At the same time the cost of labor is reduced.

The cost of hydrogen, not including charges for interest and sinking fund on the plant varies from ten to twelve centimes per cubic meter in the case of a plant of 200 cubic meters per hour capacity. With the special purification of which mention was made above, the price rises to about 12.5 to 14 centimes. It is interesting to compare these figures with the price of hydrogen as prepared by the old method of acting upon iron with sulphuric acid, where 75 centimes must be regarded as the minimum price attainable. At the same time there is little doubt that the process is open to further improvement and that ultimately the price of the product will be still further reduced.

Colloids and Crystals[*]

Two Worlds of Matter

By Robert H. Bradbury

I.

WHEN a solid is brought into contact with a liquid the result depends upon the nature of both. There may be apparently an entire absence of interaction, as when rosin is shaken up with water or chalk with alcohol. Or, as when sugar is agitated with water, the solid may disappear, entering into solution in the liquid. The study of sugar solution shows quite clearly that the connection of the sugar molecules with each other has been completely destroyed. They are dispersed through the water very much as the molecules of a gas distribute themselves uniformly in a vacant space, and in both cases the permanence of the uniform dispersion is due to the incessant motion of the molecules. Were the molecules at rest, both the sugar and the gas would settle and form a layer on the bottom of the containing vessel.

However, the molecules of the sugar retain their structure intact, the action being limited to their dispersion. When salt, on the other hand, is dissolved in water, a further breakdown occurs, the molecule is separated and ions of sodium and of chlorine move about in the liquid. Both solutions freeze below 0 deg. C. and boil above 100 deg. C. The most important difference between them is that the salt solution conducts the electric current, while the sugar solution is as poor a conductor as water itself.

A fourth possibility presents itself when glue or gelatin is treated with water. The gelatin absorbs water, swells up and, under the influence of heat, dissolves, but the liquid freezes and boils at practically the same temperatures as pure water. The study of the solution shows that the dispersion is not molecular. The particles of gelatin in it are composed of variable and rather large numbers of molecules. A system like this gelatin solution which presents a case of very fine but not molecular subdivision is called a *colloidal solution*. There are certain solids such as gelatin and dextrin (with water), rubber (with benzene and carbon disulphide), which, when they dissolve in liquids, are invariably dispersed in this way. Such solids may properly be referred to as *colloids*. They are all amorphous. Crystallized substances never yield colloidal solutions by mere spontaneous solution in a liquid. They always produce molecular or ionic dispersions. However, the phenomenon of colloidal solution is perfectly general, and crystallized substances can also be obtained in this condition, but not by mere solution.

[*] Presented at the meeting of the Section of Physics and Chemistry of the Franklin Institute and published in the *Journal of the Institute*.

It is an interesting fact that a substance which yields a colloidal solution with one solvent may form an ordinary molecular solution with another. Soap is an example. Its concentrated solution in water boils at about 100 deg., freezes at about 0 deg., and exhibits the behavior of a colloidal solution in general. On the contrary, a soap solution in alcohol shows the normal change in freezing and boiling points corresponding to the molecular weight, and conducts itself in all respects like an ordinary molecular dispersion.

II.

Every one is familiar with the distinctions between solutions and suspensions. Suspensions are turbid in aspect, and the solid can be removed by letting it settle, or by filtration. Solutions are clear, dissolved matter does not subside and is unaffected by filtering. Colloidal solutions occupy an intermediate position.

Consider for a moment the effect of increasing subdivision on a suspension of finely-divided gold in water. So long as the diameter of the particles is much greater than a thousandth of a millimeter,[1] the system will be turbid and the gold will settle rapidly. But the wavelength of visible light ranges between 0.4μ and 0.7μ, and when the particles become smaller than this they can no longer reflect light and the liquid will appear clear. At the same time there will be a rapid falling off in the speed of settling. Stokes has derived a formula for the velocity of subsidence, v, of small spheres of radius R and density S falling in a liquid of density S' and internal friction f under the force of gravity g:

$$V = \frac{2}{9} g(S - S') \frac{R^2}{f}$$

Substituting the proper values for gold and water and assuming a radius of 1μ for the particles, the value for V is about 14 centimeters per hour. This means, of course, that the system would be a coarse suspension and would clear up at once. But when $R = 10 \mu \mu$, V is only about a centimeter a month. This begins already to be fairly permanent. It must be remembered that the high density of gold (19.5) increases the rapidity of subsidence. If we make the calculation for $S = 3$, which is about the density of arsenious sulphide, V comes out only about a millimeter a month.

So much for calculation. Now what are the facts? As a matter of fact, the dispersed substance in a colloidal solution does not settle at all, so long as the subdi-

[1] It is usual to employ the symbol μ (the Greek letter mu) for the thousandth of a millimeter. In the same way $\mu\mu$ indicates the millionth of a millimeter.

vision is maintained. Colloidal gold solutions have been preserved unchanged for years. I have a solution of arsenious sulphide which has remained apparently unchanged for three years and whose countless particles can readily be seen, engaged in their incessant Brownian movement, with an ordinary oil immersion lens. Whenever settling does occur, it is preceded by the aggregation of the particles into larger particles, which finally attain a diameter of 1μ or over, and slowly subside.

Here, then, is an apparent discrepancy between Stokes's law and the facts. The law informs us that the speed of subsidence decreases rapidly with decreasing radius of the particles, but it does not lead us to expect the total absence of settling which presents itself when the average radius is $10 \mu \mu$ or thereabout.

The explanation, of course, is molecular motion, or, in other words, *heat*. The particles are battered, on all sides, by a hailstorm of molecular impacts. If the particle is large, the blows of the molecules of the solvent in different directions neutralize each other. But when the particle is not so very much larger than the molecules themselves a molecule striking, say, on the left, will give the particle a very perceptible push toward the right, "just as a cork follows better than a large ship the motion of the waves of the sea."[2] As the dimensions of the particle approach the molecular dimensions it begins to behave like a molecule and is swept along in the endless molecular movement. The cause which prevents the particles in a colloidal solution from settling is in no way different from the cause which prevents the earth's atmosphere from subsiding to a snowy layer a few feet deep on the surface of the planet.

It is worth remembering, also, that the particles of the dispersed phase ordinarily possess an electric charge, which is usually negative. The effect of the repulsion of these similar charges would be to preserve the distribution of the particles throughout the liquid. It is a fact that, when the charges are removed, the system becomes unstable and subsidence—preceded by coalescence of the small particles—readily, but not necessarily, occurs.

III.

On the subject of the classification of colloid systems we must be very brief. One proposal subdivides them into *suspensoids*, such as the sols[3] of gold and arsenious

[2] Perrin.

[3] Thomas Graham introduced the term sol as an abbreviation for colloidal solution.

sulphide, in which the dispersed phase is solid, and *emulsoids*, in which the dispersed phase is liquid. This classification would appear to be an attempt to extend the familiar distinction between liquid and solid to a domain in which that distinction has little if any meaning. To assert that a thing is solid is to say that it has a definite shape, which it retains with some persistence. There is not the slightest reason to think that the particles in a gold sol are solid. It is usual to assume that they are spherical, but this is done merely because it is the simplest assumption to make. There are faint indications that they really have the form of leaflets or of little rods, but they appear in the ultra-microscope simply as brilliant dancing points, and in reality we know nothing whatever about their shape. In connection with this it is interesting to recall the fact that the formation of a crystal begins with the appearance of minute liquid spheres (globulites),[4] which pass through several stages (margarites, longulites, etc.) before the crystal is formed. It seems possible that, under such enormous subdivision, cohesion retires into the background and surface tension assumes the chief role, so that the gold particles are rather to be compared to minute drops than to little crystals.

Enough has been said to make clear the uncertainty which attaches to the attempt to classify colloid solutions according to the state of aggregation of the particles. A better classification is into *reversible* and *irreversible* colloids, according to the way in which the dissolved substance behaves when separated from the solution. Thus, when a gelatin solution is evaporated until it "sets" it is only necessary to warm the jelly with water to obtain it again in colloid solution. Gelatin is a typical reversible colloid. But when the gold is caused to separate from a gold sol—which can easily be brought about by adding any electrolyte to the sol—the gold will not again enter into colloidal solution. Shaking or warming with water gives a mere suspension, which settles at once. Gold is an *irreversible* colloid. The distinction is fundamental. Many organic colloids are reversible, while it is rather the habit of the inorganic colloids to behave in the irreversible way.

IV.

In order to prepare a sol containing an irreversible colloid all that is necessary is to reduce the solid to extreme subdivision in a liquid in which it is insoluble. The electric arc furnishes a rapid and simple method.[5] Two gold wires about 2 mm. thick are connected with a 220-volt circuit and brought together under distilled water. A 110-volt circuit can be used, but more patience is required. Sols of platinum, silver, copper, and other metals can be made in the same way. By related electrical methods, using such liquids as pentane and anhydrous ether, Svedberg[6] obtained sols of all five of the alkali metals. The colors of the sols agreed with those of the vapors of the corresponding metals.

Chemical reduction of a salt of a metal furnishes another method which has been largely employed by Zsigmondy[7] and other investigators. For instance, a very dilute solution of auric chloride is mixed with such reducing agents as formaldehyde, hydroxylamine or an etheral solution of phosphorus. The gold sols obtained in this way are usually red by transmitted light, the particles being bright green and very much smaller than in the sols obtained by the electrical method.

By various chemical methods, which lack of space forbids us to discuss, sols of sulphides (CdS, As_2S_3, Sb_2S_3, etc) and oxides (Fe_2O_3, Al_2O_3) can be obtained. The sol of aluminum oxide is important on account of its connection with dyeing and mordanting. The formation of the blood-red sol of ferric oxide by adding a concentrated solution of ferric chloride to about 50 volumes of boiling distilled water is a simple and beautiful lecture experiment.

In making colloidal solutions of *salts*, the essential thing is to mix dilute solutions of the precipitants, using a liquid in which the insolubility of the product is as complete as possible. Thus, in mixing very dilute solutions of sodium sulphate and barium chloride, a crystalline precipitate is usually obtained. The reason is that barium sulphate possesses a very slight but real solubility in water. Hence the liquid in contact with the particles first contains enough barium sulphate to nourish their growth and allow them to develop to crystals. If alcohol is added to the sulphate, before the barium chloride is introduced, the solubility of the barium sulphate is greatly reduced, and it is obtained in colloidal solution without difficulty.

In the same way if we mix water solutions of sodium hydroxide and of hydrochloric acid we obtain merely

an ordinary solution of common salt. But if salt is produced by a reaction between organic compounds in a liquid in which the sodium chloride is insoluble, then a colloidal solution is obtained. For instance, when chlor-acetic ester interacts with sodio-malonic ester a grayish opalescent sol of sodium chloride in ethenyl tri-carboxylic ester results: $CH_2Cl\ COOC_2H_5 + CHNa$ $(COOC_2H_5)_2 = CH_2\ (COOC_2H_5) — CH\ (COOC_2H_5)_2 + NaCl$. At low temperatures, in such liquids as toluene and chloroform, even *ice* has been obtained in colloidal solution.

V.

The most striking property of the reversible colloids is that they are able to communicate their reversibility to the irreversible ones. Thus, if a trace of gelatin is added to a gold solution, the gold becomes much more difficult to coagulate by electrolytes, and when coagulated it can be dispersed again by merely warming with water. This curious protective action is exerted in, greatly varying degree, by most reversible colloids. Direct study of the phenomenon with the ultra-microscope shows that the view frequently expressed that the gelatin envelops or forms a film around the gold particles is incorrect. What actually happens seems to be a direct combination between gelatin particles and gold particles, which then pass through the reversible changes together.

Protective colloids enjoy a wide practical application. In the manufacture of photographic films the gelatin retards the crystallization of the silver bromide. Ink often contains a colloid which prevents the pigment from settling. The lubricant "aqua dag" put in the market by the Acheson Company consists of finely-divided artificial graphite, held up by a protective colloid. Clay is made plastic for the potter by an empirical process which involves the action of protective colloids derived from decaying vegetable matter. The addition of gelatin in making ice cream depends upon its protective action in preventing the growth of ice crystals, which would make the product "gritty." Without doubt protective action plays an important rôle in the cleansing action of soap. This has been made clear by some recent experiments of Spring.[8] Lampblack, freed from oil by long washing with alcohol, ether, and benzene, forms a rather stable suspension in water, but the lampblack is detained by a paper filter. If the filter is now reversed, so that the blackened surface is outward, and water poured through it, the lampblack is not removed, but a dilute soap solution removes the coating and cleanses the filter at once. Finally, lampblack suspended—or colloidally dissolved—in soap solution, passes through a filter unchanged. It is of much practical interest that there is a well-marked optimum in the concentration of the soap required to protect the lampblack. A one per cent soap solution is the most efficient. In two per cent soap solution lampblack sinks about as rapidly as in pure water.

VI.

We have already considered the probable actual condition of the particles in a colloidal solution and have concluded that, for the present, no very definite information is obtainable about the matter. We must now return, for a moment, to the subject in order to allude to the thesis so brilliantly advocated by van Weimarn, the Russian investigator, who holds that the particles are of necessity minute crystals and that there is, in fact, no such thing as amorphous matter. He even goes so far as to state that substances like air and water are in a "dynamic crypto-crystalline condition," though I have been unable to understand what he means by this statement.

Briefly, the evidence that van Weimarn adduces to the support of his hypothesis is:

(1) That colloid particles will grow to crystals if provided with the proper nourishment, namely, a dilute solution of the same substance.

(2) That colloid particles are capable, when introduced into a supersaturated solution of the same substance, of discharging the super saturation and inducing the formation of crystals.

Those who desire to follow this matter further should read van Weimarn's little book, "Grundzüge der Dispersoidchemie," after which they will find themselves very much interested, but somewhat unconvinced. Let me hasten to add that I have not the least desire to undervalue the brilliant experimental work of the Russian chemist. It is, in fact, precisely by the conception of more or less daring hypothesis, and the working out of their consequences, that our science achieves its endless victory over the nescience about us.

VII.

We have seen that the wave-lengths of the visible radiations are comprised between 0.4 μ and 0.7 μ. With objects much smaller, the ordinary microscopic method ceases to be applicable. Using ultra-violet radiation for illumination, quartz lenses in the microscope, and receiving the image with the photographic plate instead of the eye, it is possible to advance a step further in the domain of the infinitesimal, but only a step, and there

are obvious objections to the proceeding. Since some of the particles in colloidal solutions are only 0.006 μ in diameter, we can never hope to see them as little bodies subtending a visual angle. The *ultra-microscope*—the powerful instrument of investigation to which most of our knowledge of colloidal systems is due—renounces this idea and makes the particles visible merely as glittering points on a black background. The sol is placed in a small rectangular glass trough and a horizontal beam of arc light or sunlight focussed in it. The microscope is placed vertically above the trough. It will at once be seen that there are two fundamental things about the instrument: to provide intense illumination, and to make sure that no light enters the microscope except the rays which emanate from the particles. The principle is simple, but the system of diaphragms and lenses needed to secure the second object makes the ultra-microscope an elaborate and expensive instrument in practice.

Cotton and Mouton[9] achieve the same end in a different way. The illumination (arc or sunlight) is thrown up from below by a paraboloid reflector so ground that all rays, *except those diffracted by the particles*, are totally reflected from the cover-glass over the sol. This instrument is simple, easily adjusted and cheap. It is made commercially by the firm of Zeiss. It would seem to be admirably adapted to school purposes. In fact, after a look into the ultra-microscope, the study of the molecular topics ceases to be drudgery and becomes a positive intellectual need.

VIII.

Even a brief glance at the subject of colloid systems must at least mention the classic work of Perrin[10] on the distribution of the particles in suspension of gamboge and mastic. He succeeded, by an ingenious and simple method, in preparing emulsions of gamboge in water in which the spherical yellow granules were all of the same diameter. If we consider a mass of such a liquid in a tube, it is clear that the granules, if at rest, would, since they are denser than water, all fall to the bottom. The fact that they remain suspended is due to their movement. In other words, the state of things is the same as in the earth's atmosphere, and just as the molecules are more crowded near the earth's surface, so the granules of gamboge must be more numerous near the bottom of the liquid than in the upper layers. Perrin verified this prediction by direct counting of the granules under the microscope. The barometric formula which describes the progressive rarefaction of air with increasing height also describes the distribution of the granules in Perrin's uniform emulsions. The only difference is that, while the aviator must ascend six kilometers in order to reach air half as dense as at sea level, the same effect is produced, in Perrin's emulsion, by an ascent of 0.1 millimeter.

That the mean energy of rotation of a molecule must be equal to its mean energy of translation is one of the chief propositions of the kinetic theory. Perrin has proved this by direct measurement of the rotation of granules under the microscope. For this purpose, large granules (15 μ) of mastic were employed. These are far too heavy to remain suspended in water, so a solution of urea was used. Fortunately, the granules contain little inclusions which make it possible to measure their rotation.

These are only two of many fundamental results contained in this wonderful memoir. Van't Hoff extended the gas laws to solutions. Perrin has now proved them to be valid for systems in which the moving particles are visible realities. Let us end by quoting one of the sentences of his conclusion:

"*La découverte de telles relations marque le point où s'élève, dans notre conscience scientifique, la réalité moléculaire sousjacente.*"

Proposed Development of American Potash Deposits

A COMPANY—the American Trona Company—has been organized, with a capital stock of $3,000,000, to develop the deposits of potassium salts at Searles Lake, near Death Valley, California. Another organization—the Nevada Potash Company, Goldfield, Nevada—plans the development of a reported potash deposit in Clayton Lake, 20 miles west of Goldfield; it is reported that the company will commence experimental work immediately on the 160 acres controlled. The large deposits of alunite near Marysville, Utah, are controlled by the Florence Mining and Milling Company of Philadelphia, Pa.—*The Journal of Industrial and Engineering Chemistry.*

[4]Fink, *Poggendorff's Annalen*, vol. 46, p. 258 (1839); Schmidt, *Liebig's Annalen der Chemie*, vol. 53, p. 171 (1845); Frankenheim, *Poggendorff's Annalen*, vol. III, p. 1 (1860).

[5]Bredig, *Zeitschrift fur angewandte Chemie*, 1898, p. 951. For a full account of Bredig's work with the platinum sol see *Zeitschrift für physikalische Chemie*, vol. 31, pp. 258-353 (1899).

[6]*Berichte der deutschen chemischen Gesellschaft*, vol. 38, p. 3616 (1905).

[7]See his monograph, "Zur Erkentnis der Kolloide" (Jena, 1905), which has been translated by Jerome Alexander.

[8]*Kolloid Zeitschrift*, vol. 4, p. 161 (1909); *Kolloid Zeitschrift*, vol. 6, pp. 11, 109, 164 (1910).

[9]*Compt. Rendus*, vol. 136, p. 1657 (1903).

[10]*Annales de Chimie et de Physique*, 3d series, vol. 18, p. 5 (1909). There is a German translation by Donau in *Kolloidchemische Beihefte*, vol. 1, p. 1 (1910). An English translation by Soddy has appeared in book form under the title "The Brownian Movement and Molecular Reality."

Fig. 9.—Elephant colossus, Ming Tombs, China, photograph from F. B. Wright.

Fig. 10.—Great sphynx, Ghizeh, Egypt.

Fig. 11.—Elephant colossus, Ming Tombs, China, photograph from F. B. Wright.

Stone Monuments—I*

Their Relation to History and Geography

By J. Walter Fewkes

INTRODUCTION.

A SEEMINGLY well defined phase of human culture history, attained independently in localities widely separated geographically, has been designated the megalithic. The dominant racial feeling, religious or cultural, was expressed in this epoch by great commemorative monuments constructed of stone and called "monoliths," or, when sculptured in life forms as representations of animals, men, and gods, they are termed colossi.

The close connection, in the mind of primitive man, of culture and religion is preserved in the Latin word *cultus*, or its English derivative, culture, the stimulus for which is desire for improved condition of life in thought and act or a striving for higher ideals, so well brought out in Mr. Matthew Arnold's scholarly essay, "Sweetness and Light." The megalithic epoch ex-

*Abridged from the Presidential address delivered before the Anthropological Society of Washington, February 20th, 1912, and published in the Smithsonian Miscellaneous Collections, Vol. 61, No. 6.

presses objectively a consciousness of power and is largely correlated with religious feeling and the cult of the dead.

This phase in racial history culminated in the later Stone Age, and in some cases lasted long after the discovery of metals, echoes of it appearing sporadically even in the highest civilization. Many races appear not to have had a megalithic epoch in their history; in others the expression was individual, not racial; some peoples had not sufficiently advanced to have attained it, while others have progressed so far beyond this condition that its very existence is at present known only by monuments; the names and the races of the builders have passed out of memory, or are unrecorded.[1]

It is an instructive study in religious or culture history to trace the distribution of megalithic monuments characteristic of this epoch, to compare the varieties of forms they assume in different localities and consider their purpose; but the vastness of the subject limits my consideration to one aspect, monoliths and colossi,

[1] Since the habit of erecting megalithic structures is of independent origin and not derivative, the age of monoliths varies among different races. While the dynasty in which many of the Egyptian obelisks were erected is known from the inscriptions they bear, no one has yet satisfactorily determined the antiquity of the unworked dolmens and menhirs, nor is it known whether they were erected contemporaneously with obelisks or earlier.

rendering it necessary to pass over a large number, perhaps the majority, of megaliths.

Why do these monuments occur in certain geographical localities and not in others, and how are they to be interpreted by the student of human geography? What is the nature of the feeling they express?

The causes which have led one race and not another to develop a megalithic habit may be sought in certain psychical conditions difficult of interpretation, but the custom appears to have originated independently and spontaneously under different physical conditions. The erection of monoliths is not due to similarity of environment so much as to identity of thought;[2] the feeling originating subjectively rather than in response to surroundings. Westropp ("Prehistoric Phases") writes:

"It is now a generally accepted canon that there are common instincts implanted by nature in all the varieties of the human race, which lead mankind in certain

[2] A consciousness of power, always a source of personal and racial gratification, tends to express itself in huge monuments.
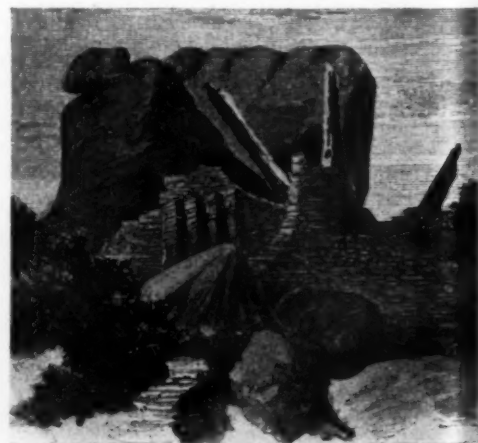
Fig. 13.—Platform monoliths, Zimbabwe, Africa, from Bent.

Fig. 12.—Portion of Stonehenge, Wiltshire, England, from Lockyer.

Fig. 15.—Colossus of soldier, Ming Tombs, China, photograph from F. B. Wright.

Fig. 14.—Carnac, Brittany, from Hunter-Duvar et alii.
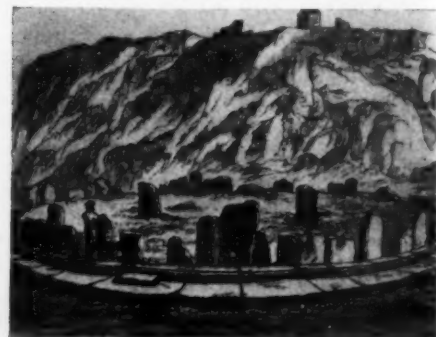
Fig. 16.—Sun-circle, Sillustani, Peru, from Squier.

Fig. 17.—Monolith, Abyssinia, from Bent.

Fig. 18.—Obelisk, Heliopolis, Egypt.

Fig. 19.—Monolith, Aksum, Abyssinia, from Bent.

climates and at a certain stage of civilization to do the same thing in the same way, or nearly so, even without teaching or previous communication with those who have done so before."

The significance of megalithic monuments is correctly pointed out by Mr. Fergusson who writes:

"Honor to the dead and propitiation of the spirits of the departed seem to have been the two leading ideas that, both in the East and West gave rise to the erection of these hitherto mysterious structures which are found numerously scattered over the face of the Old World."

In somewhat the same vein are the words of Mr. John Stuart:

"The remains of most ancient people attest that greater and more enduring labor and art have been expended on the construction of tombs for the dead than in abodes for the living."

Sir James Stimpson held somewhat the same belief:

"There is no longer reason to doubt that the Egyptian pyramids are megalithic tombs of the dead."

A study of the megalithic epoch has its historical and its geographical sides; the historian being concerned with its appearance in time; the geographer with place. The anthropogeographer embracing both in his consideration asks the pertinent question: Why has this epoch occurred at a certain place at a certain sequence in culture history and not elsewhere at another time?

It is unnecessary to remind you that culture history is not limited to written records, and that concerted actions of races, whether recorded or not, constitute their history. Those inventions that have most profoundly influenced culture, like the discovery how to make fire, are more important in results than great battles that have brought about dynastic changes.

Monoliths, as expressions of a desire to perpetuate the memory of ancestors or to commemorate past events, are naturally found only where the race had arrived at a self consciousness of its own power. Their geographical distribution[3] over the earths surface corresponds roughly with the awakening of that consciousness. The megalithic custom, therefore, has an independent origin among different people, and its prevalence among widely separated races by no means implies, much less proves, acculturation or contact. It is autochthonous and its origin, being mental, can be traced to what for a better name we call psychic influence.

The megalithic habit is necessarily dependent on the nature of convenient rock formations and other geological conditions.

It is self evident that except in so far as the production of megaliths is dependent on transportation of material used, the distribution of monoliths is largely geographical, correlated with that of stones suitable for their manufacture. Great plains or sandy deserts furnish scanty material for construction of monoliths, and if megaliths are used by people living in this environment the distribution of rivers and the direction of their flow, by which they were transported from a distance, must be given weight. Monumental structures are not to be expected in cold regions where the earths surface is covered with snow or ice clad; while generally children of the

[1]Evidences of great human antiquity are commonly found in regions where megaliths occur. It takes a long time to develop this habit or phase of thought, and monumental structures are not the product of a few years.

deserts, they occur in forested regions, and are commonly found in those regions of the earth that show a long continued habitation by man. They are tropical and warm temperate zone structures and exotic elsewhere.

Natural monoliths or huge stones, unchanged by the hand of man. have been set up by all races, occurring with equal abundance in Europe, Asia, Africa, America, and the islands of the Pacific. They are found singly, or in groups, regularly or irregularly arranged, taking the forms of rectangles, circles, and other various combinations.

OLD WORLD MEGALITHIC EPOCH.

In certain regions of the earths surface, as in France, England, the Mediterranean Islands, along the coast of northern Africa, Syria, Egypt, and India, monoliths are more abundant than in regions situated in higher latitudes. They are not found very far from the historic zone of civilization. The similarity of these objects along both shores of the Mediterranean Sea and beyond the Pillars of Hercules has suggested to some students that they were erected at the same time by the same race, but the constructors of monoliths have not necessarily a racial connection.

It is believed that the unworked monolith was used far back in human history for some religious purpose. While its erection as a commemorative object would seem to be secular and to have developed from the habit of throwing together a heap of stones to mark some event, a large stone has almost invariably acquired a religious meaning. Worship of stones is universal, the Greeks early worshipped a shapeless stone, probably a meteorite, in Ephesus that was later replaced by a beautiful statue representing Diana. The Kaaba of Mecca, as is well known, antedates the Mohammedan era; the shrine of the Earth and Fire god of the Hopi Indians of Arizona is a log of petrified wood.

The following interpretation of the structure of megaliths known as cromlechs has been suggested by Herr W. Pastor. They present three distinct regions: (1) a centrally placed altar; (2) one or more concentric

Fig. 20.—Babas, grannies, Siberia, from Castagné.

circles[4] of stone surrounding this altar: (3) an entrance passing to the holy enclosure formed by rows of stones cutting the concentric circles at right angles.

Since monoliths from their very nature are commemorative they early became the media on which pictographs were incised, and there is an instructive connection between the origin of writing and the construction of monoliths. Man first inscribed his ideas on the face of cliffs, rocks, or boulders, and it is a significant fact that the races that have invented writing have likewise been foremost in erecting monoliths. The relation, however, is not necessarily one of cause and effect. On Easter Island, for instance, where great colossi in human form exist, we also find evidence of writing. The glyphs of the Central American stelae are well known. The Egyptians who excelled all people in the grandeur of their megalithic monuments, have left the largest known corpus of hieroglyphic material. In the majority of cases the most perfect monoliths, like the obelisk and colossus, in the New World as well as the Old, bear hieroglyphics.

We find at various places in the old and new continents monoliths arranged in alignment or rectangular or circular forms which were connected with solar or stellar ceremonies. These combinations bear various names, being known in the New World as Indian enclosures, ball courts, or corrals; while in the Old World they are called dolmens, menhirs, and cromlechs.

Columns or pillars supporting roofs of buildings, which are so common in sacred architectural constructions, are regarded as monoliths related to those commemorative or religious forms we are considering.[5] In the same architectural category are huge stone blocks used in foundations or construction of buildings or monolithic roofs of tombs. The covering of the grave of Theodoric the Great at Ravenna, Italy, is a good example of this type of monolith, as are likewise the huge stones found in buildings in Japan, at Ostia near the mouth of the Tiber, in Peru, and elsewhere.

The best known of all megalithic monuments is the famous Stonehenge, in Wiltshire, England, the purpose of which has been variously interpreted by different authors. This monument consists of many monoliths and trilithons, some of which are more or less artificially worked, others natural, surrounded by rings of stone.

The stone circles of Avebury, measuring 1,200 feet across, were the largest and finest megalithic monuments in existence, "exceeding Stonehenge as a cathedral does a parish church." Other stone circles occur at Stanton Drew in Somersetshire, in the Orkneys and other English islands.

Simpler forms, like "Kit's Coty House," one of the best known dolmens in England, are reproduced almost in duplicate in Sweden, Holland, Denmark, Portugal, France, India, on the banks of the Jordan, in the deserts of Arabia, India, Syria, Mexico, and Peru.

The evidence available shows that rude undressed stones, like menhirs, dolmens, and cromlechs, are essentially sepulchral or memorial stones, but their wide

[4]Professor Lockyer finds in these circles of megaliths evidences of sun worship; according to him the concentric lines of stones represent the course of the Sun god. To Mr. Arthur Evans "it seems a universal rule that the stone circle surrounds a central dolmen or stone cist containing the remains of the dead."

[5]This theory would consider the columns of Greek temples as morphologically upright stones surrounding a sacred enclosure, rather than homologues of wooden piles of archaic pile dwellings, as taught by Sarasin

Fig. 21.—Brambanan temple façade, Java.

Fig. 22.—Stone birds, Zimbabwe, Africa, from Bent.

Fig. 23.—Boro-Bodo temple façade, Java.

distribution over the earth's surface precludes our limiting them to any one race of men. In some parts of Europe they have been ascribed to the Druids, but the presence of dolmens and cromlechs in lands where Druids never lived shows that this popular belief must be somewhat modified. In their distribution around the shores of the Mediterranean, Corsica, Sardinia, and the Balearic Islands, they seem to have followed certain laws which might lead us to refer these monoliths to a center of distribution, situated on the shore of the eastern Mediterranean, but this law can not account for the presence of similar monoliths of the New World or in eastern Asia or southern Africa.

Some of the dolmens now above ground were formerly buried and were superficially indicated by mounds or barrows. But perhaps the religious character of menhirs, cromlechs and dolmens is best indicated by those buried in mounds:

"The great Lanyon dolmen in Cornwall was uncovered about one hundred years ago by a farmer who supposed it to be a mere heap of earth which he thought might be usefully applied to farming purposes. By degrees, as the earth was carted away, the great stones began to appear and when operations were completed and all the soil had been cleared away the dolmen, much as it now exists, was disclosed containing in its interior a heap of broken urns and human bones."

A work on Irish antiquities, by Vallancey, published near the close of the 18th century, shows a plan view and section through a mound and megalith, with the chamber at the center, and passageway at the side.

The geographical distribution of megalithic remains is almost parallel with that of stone buildings, which in turn are identical with caves, natural and artificial.

Mr. Baring Gould describes and figures buried dolmens in south France upon which churches were constructed, the chamber of the dolmen serving as the crypt of the church, a perpetuation of the sacred character of a building used for religious purposes in prehistoric times before the introduction of Christianity. This fact is in evidence in its bearings on the former religious use of the megalithic monuments.

Windle,[6] in considering the use of monoliths, writes:

Such stones have been in other countries not merely memorials of some great deed or departed hero, but objects of worship, and the same was probably the case in this country.

Mr. Gomme, in an instructive work, "Survivals of Worship," shows how the reverence once attached to them persists in folk practices.

"At the village of Holme situated on one of the moors

[6] B. C. A. Windle, Life in Early Britain. London, 1897. This author also writes: "The observation of Aristotle, to which Dr. Thurnam calls attention, that the Iberians used to place as many obelisks around the tomb of the dead warrior as he had killed enemies perhaps gives a clue to the origin of this custom."

Fig. 24.—Monolith, Zimbabwe, Africa, from Bent.
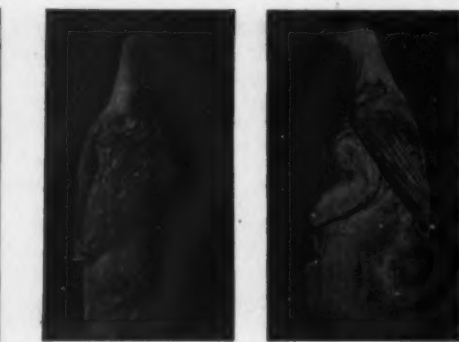
of Dartmoor is a field of about two acres, the property of the parish and called Plog Field. In the center of this field stands a granite pillar (menhir) 6 feet or 7 feet high. On May mornings before daybreak the young men of the village used to assemble there and then proceed to the moor where they released a ram lamb, and after running it down brought it in triumph to the Plog Field, fastened it to the pillar, cut its throat and then roasted it whole."

The evidence drawn from a study of the monoliths known as menhirs, dolmens, and cromlechs seems conclusive that they were connected with religious beliefs and always related in some way to the dead or mortuary ceremonials. In western Europe these stones have long since ceased to be used in religious rites, although survivals of former ceremonials persisting in peasant folk lore, are significant. We must look elsewhere in other lands where similar objects occur for light upon the meaning of monoliths. Asia and Africa furnish important aid in this study.

Herr Kremer in his accounts of the ancient cults of Arabia makes frequent allusions to natural stone worship, and in the village of Tarf there was worshipped a great irregular stone block identical with a goddess whom Herodotus called Urania. The Phœnicians were very much given to the worship of stones called baetylia, and wherever the influence of this wide roving race of traders was exerted there these monoliths are found. They are scattered along routes of trade of this people and to a degree their distribution follows the same law as that of Greek colonization so ably pointed out by Prof. Myers. Apparently the same paucity of these monuments is found on the coast of the Adriatic Sea, for the same reason that it has no Greek colonies. These baetylia are most abundant where Greek and Phœnician settlements, especially the latter, are most numerous.

Certain districts of India, as the Neermul Jungle, are said to swarm with monoliths and megalithic monuments. In Berrary, alone, Dr. Forbes Watson counted 2,129 megalithic monuments, and menhirs, cromlechs, and dolmens have been recorded in Sorapoor and Khasia; they also occur elsewhere among the hill tribes. The Todas in the Nilghery Hills have large stone circles similar to those of England, and in the Deccan, in India, villages are said to have circles of large stones sacred to Vetac. Col. Leslie records stone circles in Ceylon, and according to Palmer there are stone circles over 100 feet across near Mt. Sinai in Arabia, where Kohen mentions three large stone circles consisting of lofty trilithons 10 feet high, standing on raised foundations. Stone monuments occur in Morocco, Algiers, Tripoli, and along the whole coast of northern Africa; Lieutenant Oliver has compared the megalithic structures found in Madagascar, among the Hovas, with those of the Channel Islands.

The upright stones of some of the East Indian dolmens in the Deccan are, according to Capt. Meadows Taylor, perforated and used by the natives for various purposes one of which is to facilitate the passage of food to the manes of the dead.

Similar "holed-stones," according to Mr. W. G. Wood-Martin, which "may, in most instances, be regarded as pillar-stones," are found in Ireland: they occur in Scotland, England, and France, and thence they can be traced to India. It is stated that in the last mentioned country these perforated stones are "used by devotees, as a means of attaining forgiveness of sins, or for spiritual regeneration. If the hole is large enough, the suppliant creeps through, but if it is small the hand alone is passed through."

The artificial monolith includes all single stone monuments of size worked by human hands, from a rude hewn slab set on end to a finely carved obelisk inscribed with hieroglyphs. Some of these stones are enormous in size, but how they were cut from the quarries and transported long distances are facts difficult to explain with our limited knowledge even of the Egyptians, whose every art and craft is illustrated on the walls of tombs and temples by picture writing. Many of these large stones were apparently moved without the use of ma-

chinery, yet we find this accomplished without leaving any traces of roads or highways. To indicate the magnitude of the work of transporting these great stones consider the amount of labor in transporting the monolithic pillars of the Treasury building in Washington, which are among the largest single stone blocks in the United States, and have been calculated to weigh 38 tons; some of the Egyptian obelisks weigh 300 tons, or nearly eight times as much.[7]

The columns or pillars of the Cathedral[8] of St. John the Divine in New York are even larger than the monoliths of the Treasury building.

Several of the obelisks quarried and moved by the Egyptians weighed several times as much as these.

The estimated height of the Lateran obelisk is 105 feet 6 inches and its weight 510 tons; Cleopatra's Needle in New York is 69 feet 6 inches high and weighs 224 tons. The obelisk still in the quarry at Syene is 95 feet long and it is estimated to weigh 770 tons, which may be a greater weight than the Egyptians could move.

At the great ruin Zimbabwe, in South Africa, there are huge boulders about 50 feet high; immediately below the highest is a curious little plateau adorned by huge monoliths and soapstone pedestals supporting gigantic stone birds, the tallest of which stood 5 feet 4 inches in height. Several of these monoliths are decorated with life figures, one of which, 11½ feet high, is made of soapstone and adorned with geometrical patterns. In Bent's account of this ruin occurs the following forcible description:

"Such is the great fortress of Zimbabwe, the most mysterious and complex structure that it has ever been my fate to look upon. Vainly one tries to realize what it must have been like in the days before ruin fell upon it, with its tortuous and well-guarded approaches, its walls bristling with monoliths and round towers, its temple decorated with tall, wierd-looking birds, its huge decorated bowls, and in the innermost recesses its busy gold-producing furnace. What was this life like? Why did the inhabitants so carefully guard themselves against

[7] The monument of Emperor Alexander I, standing in front of the winter palace in St. Petersburg, probably the most remarkable monument of artificial monolith in existence, is a cylindrical pillar of one solid piece of granite 78 feet high and 12 feet in diameter.

[8] The granite monoliths (columns) for the cathedral being built at Morningside Park, New York, were quarried at Vinal Haven, Maine. The columns at present in place are 54 feet in length and 6 feet in diameter, each weighing 160 tons, or two-thirds as much as Cleopatra's Needle in Central Park. For dressing and polishing these granite columns they are mounted in a giant lathe and revolved so as to bring their exterior surface first against cutting tools and afterward on polishing materials. This lathe is 86 feet long and weighs 135 tons, and the rough stone which it reduces to dimension, weighs at first as much as 310 tons. This lathe was designed and patented by engineers of Boston, and was constructed in Philadelphia. (American Geologist, Vol. 27, No. 1, January, 1901, p. 66.)

Fig. 25.—Monoliths and images (fallen) Easter Island, from Thomson.

attack? A thousand questions occur to one which one longs in vain to answer. The only parallel sensation that I have had was when viewing the long avenues of menhirs near Carnac, in Brittany, a sensation at once fascinating and vexatious, for one feels the utter hopelessness of knowing all one would wish on the subject. When taken alone this fortress is sufficiently a marvel; but when taken together with the large circular building below, the numerous ruins scattered around, the other ruins of a like nature at a distance, one cannot fail to recognize the vastness and power of this ancient race, their great constructive ingenuity and strategic skill."

OBELISKS.

The most finished type of monolith is the obelisk, a stone structure best represented in the valley of the Nile and adjacent territory. In architectural proportions the Egyptian obelisk is a perfect monolith. Although from the early times transported by conquerors of Egypt to different localities in Europe and adopted throughout the world as a commemorative or mortuary monument, the obelisk in its present form originated in a narrow geographical area skirting the Nile, in northeastern Africa.

The purest type of obelisk, like that of Heliopolis, is a monolith tapering from base to apex, its height being about 10 times the length of one side of the base. In true obelisks all four faces are plain surfaces equal in width, although sometimes as observed by Verninac at Karnak there is a marked entasis or convexity similar to the curves in pediments of temples. When obelisks bear hieroglyphics they are regularly arranged in three rows reading from above downwards, the oldest vertical row being always in the middle.

The original inscriptions on some obelisks have been erased and new ones added, a method adopted by some rulers to express their consummate egotism.

The various Egyptian obelisks not only vary slightly in proportions but also in decorations: some have pictures and inscriptions, others not. There is a variety in mounting; thus, the obelisk of the Piazza del Minerva in Rome and one at Catania in Sicily are carried on the backs of stone elephants. Supporting the corners of Cleopatra's Needle now in Central Park, New York, were bronze props representing crabs, which probably belonged to a later cult and were placed under this monolith when it was first moved and set upright in Alexandria.

Egyptian obelisks, as those of Karnac (Thebes), commonly stood in pairs before the gates of the temples and were made of hard stone obtained from quarries at Syene, from which fact the word syenite has come to designate this geological formation. They commemorate the deeds of rulers whose cartouches they bear, accompanied by invocations and grandiloquent references to the mighty deeds of the builders, or subsequent rulers.

Many theories have been framed to explain how these obelisks were quarried. A large specimen still remaining in place in the quarries at Syene is attached to the rock by one side, the other three sides having been fashioned into shape. It is supposed by some authorities that the form of the obelisk was first marked out on the surface by cutting a groove, and that the rock was cracked by first building fire on it, after which the ashes were swept away and water poured into the groove—a method still used at the present day by the East Indians. Other authorities have supposed that holes were made at intervals and a series of wedges was placed in these holes and thus the stone was cracked off. Having been quarried the obelisk was dressed and inscribed, after which it was moved to its future home. The means by which it was transported on rafts are known, but how the great weight was set on end after the obelisk had been brought to its future site is as yet not clear.

As we depart from the Nile, the home of the obelisk, southward into Abyssinia, we find representations of the obelisk of somewhat different forms and probably of different development. The main difference outside of the form appears to be the absence of inscriptions and a departure from the square section with equal faces.

The best Abyssinian obelisks would seem to represent sacred buildings, or sun houses consecrated to Baal, being connected with sabeism or sun-worship, a pagan cult that antedated the introduction of Christianity into Abyssinia, but which has left in that country several architectural survivals, among which may be mentioned circular churches with doorways at the cardinal points, and ceremonial rites as dances before the church altars.

The monoliths of Russia, commonly called babas, or old women, grannies, may be classified as colossi and are probably of Mongol origin, being found from Mongolia to the banks of the Danube. They represent a connecting link between the statue menhirs or engraved dolmens of Aveyron, south France, the "steinfiguren" of Germany and the colossi of China, to all of which they are akin. They show that monoliths and colossi are the same in intent, and that the basal principle of both is ancestor

worship or the almost universal cult of the dead.

COLOSSI.

The highest expression of the megalithic art appears in great single stones carved into life forms known as colossi, of which the statues of Memnon are good examples. In these monoliths man attempted to express his ideas of the greatness of his gods or ancestors by the mammoth size of his idols.

We detect very clearly in the colossus the influences of geographical environment. They can be traced to a sedentary life, for a wandering people is not one that produces great sculptures. The dependence of the sculptor on available rock formation has long been recognized, for the production of a colossus of great size is impossible unless a certain kind of rock is available for that purpose. Colossi were made in the most advanced stage of the megalithic epoch and are abundant in both the old and new worlds.[9]

With exception of the sculptured menhirs, "steinfiguren," and babas, European colossi are small and inconspicuous. Monolithic colossal statues are not characteristic of ancient Greek, Etruscan, or Roman art in Europe, but occur in Asia,[10] northern Africa, Central America, and Polynesia.

We find some of the largest known colossi in Egypt where the megalithic age reached its highest development. The great sphinx at Ghizeh, the statue of Rameses II[11] and the enormous seated figures of the vocal Memnon, at Thebes, one of which is still a monolith, attest the

Fig. 26.—Temple and obelisk, Karnac, Egypt, photograph from Lekejan.

barbaric power of the ancient Egyptians in this line of expression.

In the buried cities of Ceylon there are many monoliths and colossi of Buddhas. The interior of the first temple of Dambulla contains "the gigantic recumbent figure of Buddha, which together with the pillow and couch on which it rests, is cut of the solid rock, and measures 47 feet in length." "The reclining figure of Buddha," says Burrows in his description of Gal Vihara (rock temple) of Ceylon, "is by far the finest of the three. It measures 46 feet in length and has suffered little from the ravages of time."

The colossi of China are best illustrated by the stone figures lining the road or dromos to the tombs of the Ming dynasty, about 40 miles north of Pekin, recalling the avenue of colossal sphinxes in Egypt. These huge images take the forms of men, griffins, elephants, camels, and turtles, 32 in number, arranged in pairs; one of the latter having an obelisk on its carapace reminds one of the elephant bearing an obelisk now in the Piazza del Minerva at Rome, and can be traced directly to Mongol influences, although in southern China where it is not as strong, giant images of Buddhas are frequently encountered.

The existence of colossi on Easter Island, one of the most isolated islands of the Pacific Ocean, so far from all other monumental works of magnitude, is one of the

[9] In modern times we find allegorical figures, as the statue of Liberty at the entrance to New York harbor, that of Walhalla at Ratisbon, Bavaria, or the statue of Ariovistus, Germany, taking a colossal form. While the religious feeling is absent the commemorative element still survives, and is expressed in these and many other sporadic instances that might be mentioned.

[10] The terrace on which the temple (of Baalbec) stands is formed of stones of enormous magnitude; at the northwest angle are three stones, two of which are 60 feet, and the third 62 feet 9 inches in length. Hodder M. Westropp, Handbook of Archaeology, 1867.

[11] This stupendous statue now in fragments measured 22 feet 4 inches across the shoulders. Sir G. Wilkinson estimated that the whole mass entire weighed 887 tons.

archeological enigmas. Here and there on Pacific islands there are stones that may be called monoliths, but the images of Easter Island surpass them all in size and importance.

The latter are thus described in a report on a visit to this island in 1876 by Paymaster William J. Thomson, United States Navy:

In order to form an estimate of the magnitude of the work performed by the image-makers, every one on the island was carefully counted, and the list shows a total of 555 images...... Of this number 40 are standing inside of the crater...... The largest image is in one of the workshops in an unfinished state and measures 70 feet in length; the smallest was found in one of the caves and is a little short of 3 feet in length. [One of the largest images that has been in position lies near the platform which is ornamented, near Ovahe; it is 32 feet long and weighs 50 tons......

The images were designed as effigies of distinguished persons and intended as monuments to perpetuate their memory. They were never regarded as idols, and were not venerated or worshipped in any manner......

The work of carving the image into shape and detaching it from the rock of which it was a part, did not consume a great deal of time, but the chief difficulty was, in the absence of mechanical contrivances to launch it safely down the slope of the mountain and transport it to a distant point. It was lowered to the plain by a system of chocks and wedges, and the rest was a dead drag accomplished by main strength. A roadway was constructed over which the images were dragged by means of ropes made of indigenous hemp, and sea-weed and grass made excellent lubricants. The platforms were all built with sloping terraces in the rear, and up this incline a temporary road-way was constructed of a suitable height, upon which the statue could be rolled until the base was over the proper resting place. The earth was then dug away to allow the image to settle down into position, the ropes being used to steady it in the meantime......

The fact that these huge monoliths rise from platforms recalls conditions in South Africa already considered where monoliths and gigantic birds stand on similar great stone platforms.

There is abundant evidence that Mr. Thomson has correctly interpreted the Easter Islands colossi as "effigies of distinguished persons...... intended as monuments to perpetuate their memory." Investigation of the monoliths and colossi of other Polynesian islands points to the same conclusion regarding them.

(To be continued.)

Steel for Permanent Magnets

STEEL containing 5½ per cent tungsten makes excellent permanent magnets. The steel should be heated above the recalescence point and when quenched should show a fine-grained fracture. After magnetizing a magnet should be "aged" by prolonged heating in boiling water or steam. A short bar magnet tends to lose its magnetism quickly; the coefficient of demagnetization for a bar magnet twenty-five diameters in length is 0.05 while that of a magnet five diameters long is 0.5, or ten times as great. A bar magnet five hundred diameters long is supposed to be permanent. The magnetic force of the best magnets is considered by Prof. S. P. Thompson to be only 60 to 80 per cent of what may be eventually attained.—*Machinery*.

The Distribution of Wind Velocity Around a Rod*

Cooling Effect Upon Hot Wire Used To Measure Air Current

By Prof. J. T. Morris, M. I. E. E.

A FEW years ago the author had the keen pleasure of standing on the gallery of an isolated lighthouse outside the lantern in half a gale. He was then much impressed by the variations in the apparent strength of the wind on making a complete circuit of the gallery. As was to be expected, to the leeward side of the lighthouse there was a very marked "wind shadow," in which there was more or less complete shelter from the wind. To either side of this shadow the wind was so fierce that the author had a little doubt at first whether it would be possible to keep his feet. The mere opening of the mouth caused him to whistle, though in rather an erratic manner, without using the lungs at all. But on the windward side, when facing right up into the wind, there was a comparative calm, which was most noticeable, though at the same time the wind could be heard screaming in the wind-vane and other more exposed parts of the lighthouse. In so far as its magnitude was concerned this marked cushioning effect came as a surprise to the author.

That these effects are present is common knowledge among lighthouse-keepers, but as far as the author is aware their magnitude has not been determined.

As an opportunity presented itself a short time ago of determining quantitatively the effects in a somewhat similar case—though on a small scale—the matter was put to the test of direct experiment.

The actual problem set, in the present instance, was to determine the distribution of wind velocity in the space surrounding a circular rod, when placed with its axis transversely, as an obstacle in the path of a uniform current of air.

A vertical wind-tunnel was used, whose horizontal cross-section was one foot square, and at a point half-way down this tunnel the circular rod—0.825 inches (21 mm.) diameter—was fixed with its axis horizontal, and therefore at right angles to the principal direction of the air-current. To this circular rod were attached electrically-heated wires, the cooling of which by the air-current was used as a measure of the wind velocity. The electrically-heated wires were so supported that they could be moved at will further from the circular

*Reproduced from Engineering.

rod or nearer to it. The rod was so mounted that it could be rotated on its axis in the wind-tunnel while the air-current was flowing, and as the heated wires were mounted on the rod they were carried around with it. The velocity distribution surrounding the rod at a given distance from its axis was thus explored. This experiment was repeated, with the electrically-heated wires, at various distances from the axis, and in this manner the whole of the field was mapped out.

The apparatus employed consisted of a simple form of Wheatstone bridge, supported in the air-current, a four-volt accumulator, an adjustable resistance, and some form of millivoltmeter. For this purpose a "Record" 50-ampere moving coil instrument, with its shunt removed, was used. It was of the recent long-range type, as this makes a very compact instrument when the length of scale is considered, and it is exceptionally dead-beat. The Wheatstone bridge was made up of alternate arms of manganin and of platinum, two of the arms being made each of 6 inch of No. 30 S. W. G. manganin wire, the other two arms of platinum wire of No. 40 S. W. G., and each 2.62 inches in length.
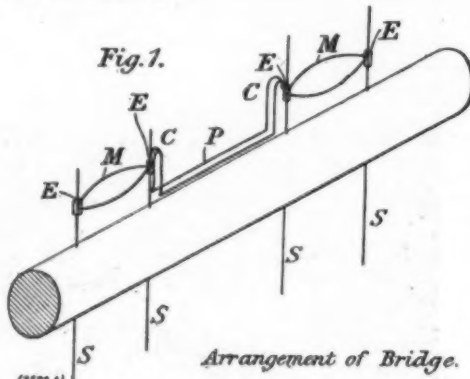
Fig. 1.—Arrangement of bridge and attachment to Rod.
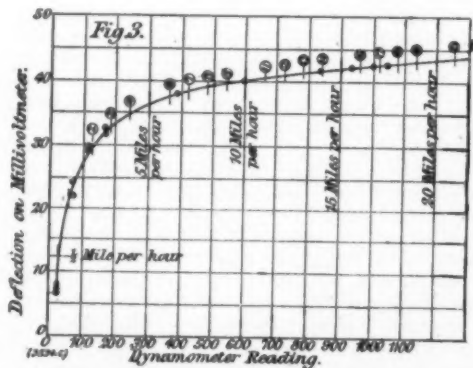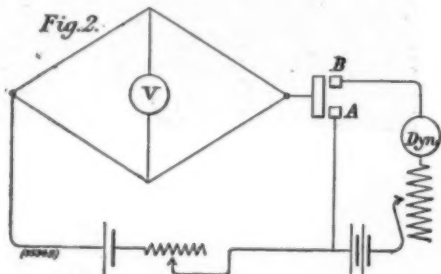
Fig. 2.—Diagram of electrical connection. Fig. 3.—Calibration curve of instrument.

The general arrangement of the bridge and its method of fixing to the circular rod is shown in Fig. 1. It was carried by means of four ebonite collars E, which could slide with friction upon the four steel guide wires S. The two platinum wires P were arranged side by side, the distance separating them being as small as it could be made without incurring the danger of the two wires touching. The actual distance was 2 mm.

As is well known, the electric resistance of manganin is practically independent of temperature, while that of platinum rises 0.0038 per degree Cent. of temperature. With the lengths given above the resistance of the platinum wires at the normal temperature of the

atmosphere is less than that of the manganin wires. By passing a current of about 1.4 amperes through the bridge it is heated to such a temperature as to bring it into balance in still air. This occurs with a temperature rise of about 85 deg. Cent. in this particular bridge. When the wires are cooled, the resistance of the platinum, but not of the manganin, is reduced, and a deflection is produced on the millivoltmeter.

The diagram of the electrical connections used is given in Fig. 2. It will be noted that besides the circuit used for normal working, i. e., the Wheatstone bridge, battery, rheostat and millivoltmeter, there is a two-way plug-key A B, which enables more battery power to be used together with a longer range rheostat and a Siemens dynamometer. This additional apparatus was used in the way described in a paper read at the Dundee meeting of the British Association, with the object of determining the relative indications of the millivoltmeter in terms of wind velocity from ½ mile per hour up to a velocity of about 20 miles per hour. This calibration curve is reproduced in Fig. 3. The absolute value of the velocity scale was obtained by means of a Pitot tube and xylol gage at a velocity of between 18 and 19 miles per hour.

When adjusting the balancing current through the bridge, before carrying out a series of experiments, it is desirable to shield the platinum wires from all air-currents, including convection currents, as far as possible, in order to obtain the highest degree of accuracy. For work of higher precision than that which was aimed at in the present paper it would be advisable to introduce certain slight modifications, such as the use of one instead of two heated wires, in order that the line over which the average velocity is to be measured might be more accurately determined.

The experiments which have been carried out with the apparatus described above are as follows:

In an air current of approximately 15 miles per hour the velocity distribution around the rod was determined at a distance of 1.5 mm. for every 10 deg. throughout a complete revolution of the rod. This experiment was then repeated with the main velocity reduced to approximately 5 miles per hour.
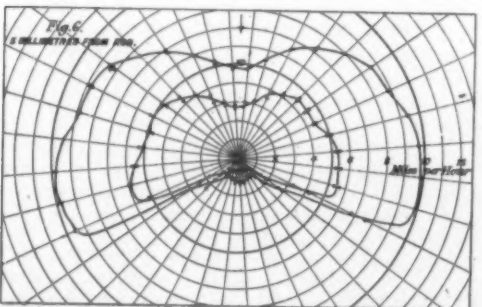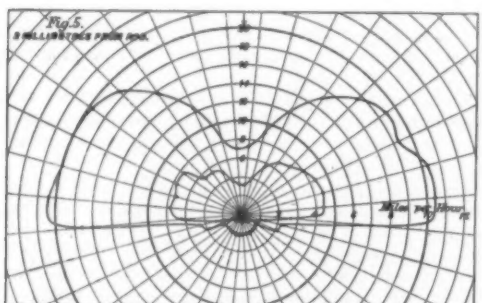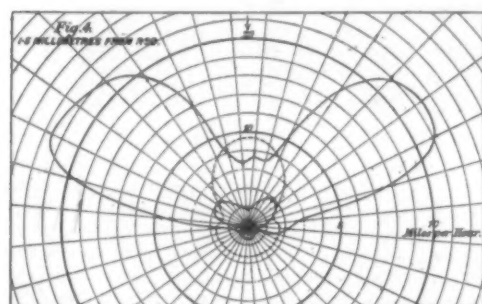
Figs. 4, 5 and 6.—Diagrams of wind velocities at 1.5, 2 and 5 millimeters from rod.
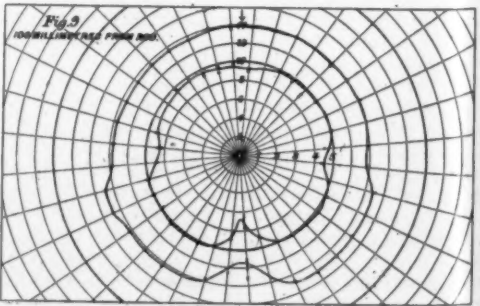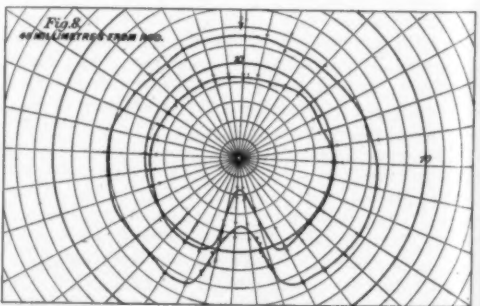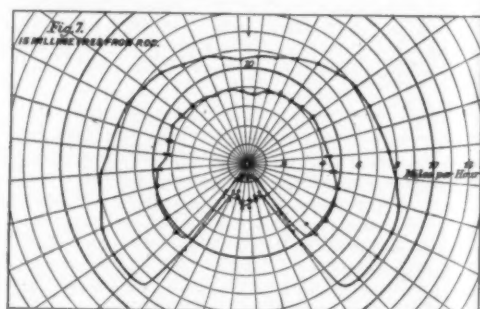
Figs. 7, 8 and 9.—Diagrams of wind velocities at 15, 45 and 100 millimeters from rod.
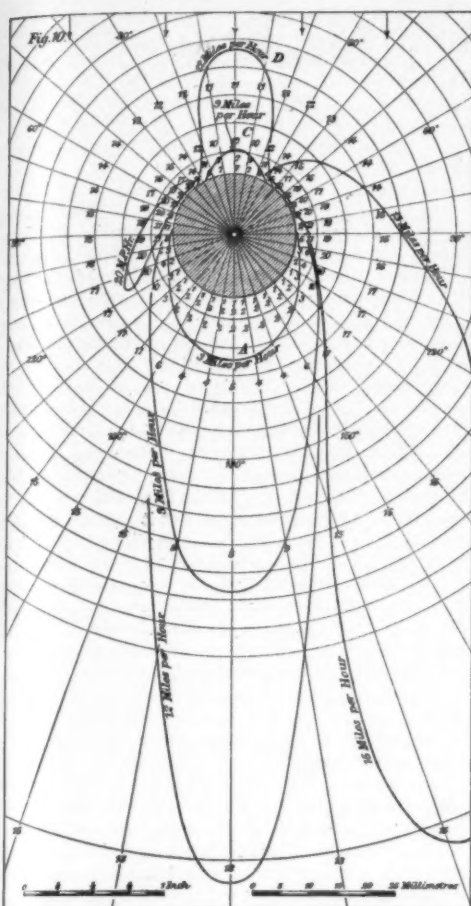
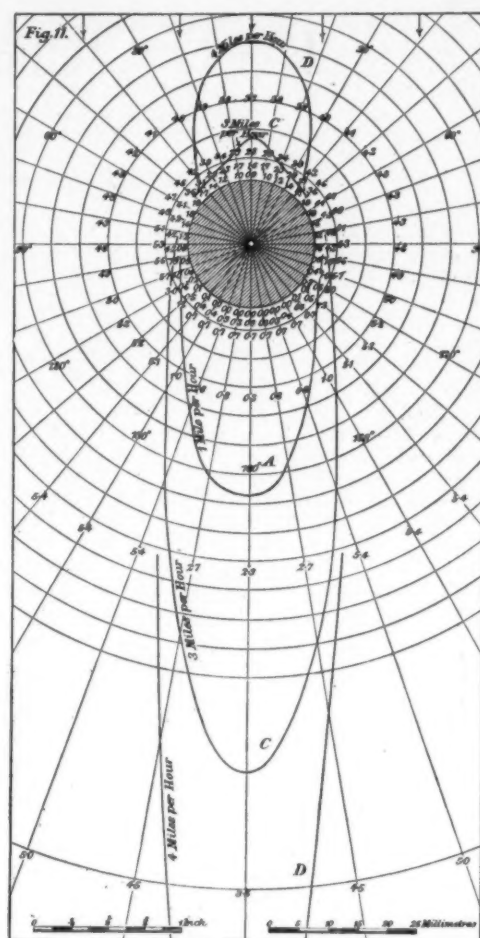Fig. 10.—Velocity contour lines in a 15-miles-per-hour air-current.

Curves representing these results graphically are shown in Fig. 4, in which the arrow at the top shows the direction of the current. The wind velocity is plotted along radial lines from the center, the distance from circle to circle having two values. On the scale to the right of the center it will be seen that the distance from circle to circle represents 1 mile per hour, while on the scale vertically above the center it represents 2 miles per hour. The former scale measures the velocities of the 5-miles-per-hour wind shown on the inner butterfly diagram, and the latter for the larger 15-miles-per-hour diagram. The dotted figure will be referred to later. Similar sets of experiments were carried out at distances of 2 mm., 5 mm., 15 mm., 45 mm., and 100 mm., and the graphical results are shown in Figs. 5, 6, 7, 8, and 9. In each of these figures the outer curve refers to the higher velocity and it should be noted that the velocity distribution in the 5-miles-per-hour current is again shown to double scale in order to facilitate comparison with the 15-miles-per-hour curve on the same figure. If the inner curves in Figs. 4 to 9 were printed on one diagram, they would show the wind velocities around a rod immersed in a 5-miles-per-hour wind measured at distances of 1½ mm., 2 mm., 5mm., 15 mm., 45 mm., and 100 mm. from the surface of the rod along 36 radial lines. Similarly, the larger curves would give the same information for the atmosphere around the rod in a 15-miles-per-hour wind.

The collected results of these experiments are gathered in the two charts, Figs. 10 and 11.

These two charts represent—the one for 15 and the other for 5 miles per hour—the velocity distribution in a plane at right angles to the axis of the rod, and therefore in a plane containing the main direction of the air-current. The velocities in miles per hour are indicated by numerals at various points, and, of course, are not to be measured along the radial lines as in the former curves. Actual distances from the rod are measured along the radial lines, and the numerals represent the velocities at the points where they occur. The rod is shown in section to scale in the center of the diagram.

On these two charts certain curves have been drawn. These curves inclose areas in which the velocity is above or below a certain stated value, and since they connect together those points where the velocity is the same, the curves may be termed "velocity-contour lines." These lines, therefore, may be compared to the contour lines which appear on an Ordnance Survey map, the only difference being that in the Ordnance Survey map places of equal height are connected together, while in the charts appended, points at which the velocities are equal are connected.

The velocity-contour lines which have been drawn on Fig. 11, of 1, 3, and 4 miles per hour, have ratios to the main wind velocity of ⅕, ⅗, and ⅘, while on Fig. 10 the

corresponding contour lines have been drawn—i. e., 3, 9, and 12 miles-per-hour. This enables a comparison of the two charts to be made more readily.

On examination, many interesting facts are revealed. Taking the 15-miles-per-hour chart first, it will be noticed that the maximum velocity attained is rather over 23 miles per hour, being an excess of 55 per cent over the velocity of the main stream. If 0 degrees is taken as the line facing straight to the wind, then one tenth of a diameter away from the circular rod a velocity of 20 miles and over is obtained from 60 degrees to 90 degrees; while at a distance of one quarter of a diameter away the same high velocity is found between 90 degrees and 110 degrees. At 5 miles per hour the maximum observed velocity is only 5.7 miles per hour, corresponding to an increase of only 14 per cent over the velocity of the main stream; it occurs at 110 degrees and at a distance of one quarter of a diameter.

Another matter which is clearly brought out is the "shadow" of the rod in the air-current. This, it will be seen, extends much farther at the low velocity than at the high. For example, directly behind the rod—i. e., at 180 degrees—at a distance of 0.5 of a diameter the velocity is one fifth in the 15-miles-per-hour current, while in the 5-miles-per-hour current a velocity of one fifth is obtained at a distance of one and a half diameters away—i. e., three times as far away.

In fact, it is clear that the extent of the disturbance produced by the rod covers a much larger area in the case of the small velocity than in that of the high.

Again, the cushioning effect, referred to at the beginning of this paper as quite noticeable when one was facing the wind in the case of the lighthouse, is shown clearly in these two charts. It will be seen from such a position the velocity of the wind may be reduced to one third or even to one fifth of the main velocity.
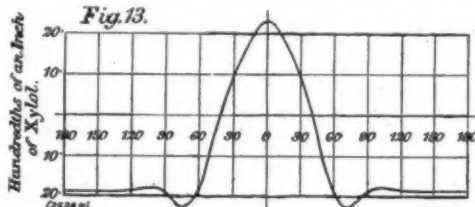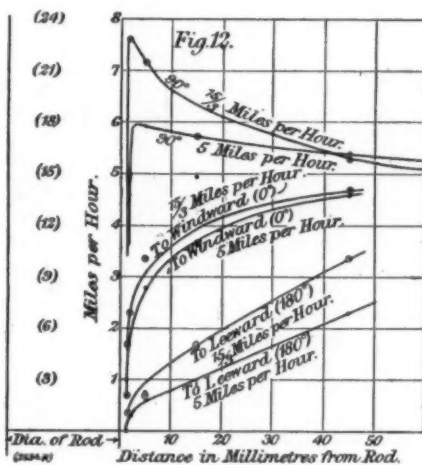

Fig. 12.—Curves showing variation of wind velocity with distance from rod. Fig. 13.—Pressure distribution around brass rod.

In Fig. 12 are collected the results which show how the velocity varies as the distance is increased from the rod for both 15 and 5 miles-per-hour. These are given in a direction facing the wind, then at right angles to the main direction of the wind, and finally in a direction receding from the wind. It should be borne in mind, when considering the results, that the rod itself will produce a certain throttling effect owing to the fact that the wind tunnel is not sufficiently large to be regarded as "infinite," for in the case examined the rod reduces the effective area by about 7 per cent.

As to the accuracy which has been attained, all the observations at any one distance from the bar are probably relatively accurate to 1 or 2 per cent; but owing to the apparatus having to be dismantled during the progress of the experiments for other purposes, on reassembling in order to complete the work, it is possible that the absolute values of the velocities for the various distances do vary to a greater extent.

Another point which has been investigated is the pressure distribution around the rod, and its relation to the velocity distribution.

In Fig. 13 is shown graphically the pressure distribution around a brass tube of precisely the same diameter as the wooden rod on which all the velocity experiments were carried out in an air-current of approximately 15

Fig. 11.—Velocity contour lines in a 5-miles-per-hour air-current.

miles-per-hour. The observations from which this curve has been drawn were kindly supplied to the author by Dr. A. P. Thurston at the beginning of this year. It will be observed that this curve is steepest at an angle of 54 degrees on either side of the zero or central position; the angle between these two positions is therefore 108 degrees. At these two positions, as the curve is steepest, the pressure gradient is a maximum, and therefore the driving force tending to accelerate the air in its passage from one point to another is here a maximum, and one would expect that the velocity of the air-current should be a maximum at some point beyond this, in the direction of the air-current. It will be seen from what follows that this is actually the case. The experimental results obtained for the velocity at 1.5 mm. from the surface of the rod, as shown in Fig. 4, give the points of maximum velocity 120 degrees apart. It will be found that the point of maximum pressure gradient on the surface of the rod is distant from the highest measured point of maximum velocity by about 2 mm., and probably this distance would be found to be even less had measurements been made of wind velocity nearer to the surface of the rod. On Fig. 4 the pressure distribution on the surface of the rod is set out in dotted lines in the form of a polar diagram, which has certain advantages; but one must beware of taking the slope from this curve in order to get the point of maximum pressure gradient, as it will obviously give an erroneous result.

Many other interesting points are brought out by a closer study of the results, but before laying too much stress upon them, they require confirmation by further experimental work.

In conclusion the author wishes to say that he is convinced that the electrical method of measuring wind velocities is a method at once reasonably accurate and capable of easy application in many experimental problems in the field of aerodynamics, for example, in experimentally testing in a quantitative manner the theory of "dynamic similarity," and that, in his opinion, a thorough study of its capabilities would well repay anyone engaged in researches in aerodynamics.

To Commence Seventh Avenue Subway.—Within a few weeks time work will begin on the Seventh Avenue Subway—one of the most important stretches in the whole rapid transit system. It will begin at Times Square, 42nd Street where it will connect with the existing Subway, and run southward through Seventh Avenue, Varick Street, West Broadway, and other streets to the Battery, and by tunnel to Brooklyn. Upon its completion New York city will possess a continuous West-side route from Harlem to the Battery.

Chemical Production of Light[*]

Will the Lamp of the Future Give Us "Cold" Light?

By Prof. Wilder D. Bancroft

For many years the firefly has been an object of admiration and envy to the chemist. The firefly produces light in a very efficient way. The spectrum of the emitted light consists of a narrow band in the yellowish-green portion of the visible spectrum, apparently unaccompanied by any emission in all the ultra-violet or ultra-red portions of the spectrum. As yet, the chemist cannot duplicate this result in spite of the fact that the light of the firefly is due to chemical action. When oxygen is absent, no light is given out. The light is not necessarily connected with the life of the firefly. The dry, powdered, abdominal material of the insects can be kept for as much as two years and will then emit light if moistened and exposed to oxygen. If the chemist could duplicate the abdominal material in the laboratory, he would have a substance which could be made to emit light having the same characteristics as the light emitted by the fireflies.

The chemist cannot do this as yet, and it is not necessary that he should try to, because there are undoubtedly other substances which would be easier to make and which would work equally well. The problem is to find out what these other substances are. There are certainly two ways of attacking a problem like this. One method has been made famous by Edison, and consists in trying every conceivable substance to see which one will be satisfactory. While this method has worked well with Edison in many cases, at any rate up to a certain point, it has not been a striking success in the hands of others, and it is not a method which appeals to a college professor. The Edisonian method is one extreme, and the other extreme is the professorial method. I cannot apply my own name to it, because it was carried to perfection long before I was born. The professorial method, as applied to our problem, consists in studying the way in which light has been produced from primeval times to the present, after which one would naturally discuss the whole theory of the production of light. This method has the advantage of enabling one to write an incredible number of papers without much effort. It is also possible to drop the subject whenever it becomes too difficult; according to Mr. Edison, this is what usually happens.

The professorial method is the one that I am going to consider, though I shall not go back so far as to quote from a paper that I think I once read, on the kind of oil used in the lamps in the hanging gardens of Babylon. At the present day, artificial illumination is caused chiefly by heated solids. In the case of the incandescent lamp, this is obvious; but there might be some question about light from gas or oil.

This point has been discussed by Mendeleeff[1], from whom I quote:

"Flames are of different degrees of *brilliancy*, according to whether *solid* incandescent particles occur in the combustible gas or vapor, or not. Incandescent gases and vapors emit but little light by themselves, and therefore give a paler flame.[2] If a flame does not contain solid particles, it is transparent and pale, and emits but little light.[3] The flames of burning alcohol, sulphur, and hydrogen are of this kind. A pale flame may be rendered luminous by placing fine particles of solid matter in it. Thus, if a very fine platinum wire be placed in the pale flame of burning alcohol—or, better still, of hydrogen—then the flame emits a bright light. This is still better seen by sifting the powder of an incombustible substance, such as fine sand, into the flame, or by placing a bunch of asbestos threads in it. Every brilliant flame always contains some kind of solid particles, or at least some very dense vapor. The flame of sodium burning in oxygen has a brilliant yellow color, from the presence of particles of solid sodium oxide.[4] The flame of magnesium is brilliant from the fact that in burning it forms solid magnesia, which becomes white hot, and similarly the brilliancy of the Drummond light is due to the heat of the flame raising

the solid non-volatile lime to a state of incandescence. The flames of a candle, wood, and similar substances are brilliant, because they contain particles of charcoal or soot. It is not the flame itself which is luminous, but the incandescent soot it contains. These particles of charcoal which occur in flames may easily be observed by introducing a cold object, like a knife, into the flame.[5] The particles of charcoal burn at the outer surface of the flame if the supply of air be sufficient; but, if the supply of air be insufficient for their combustion, the flame smokes, because these unconsumed particles of charcoal are carried off by the current of air."

With incandescent solids, the intensity of the light is a function of the temperature, increasing rapidly as the temperature rises, and being independent of the nature of the solid if this is so arranged that it gives what is known as black body radiation,—in other words, if the conditions are such that no light can be reflected by the incandescent solid. This condition is not fulfilled strictly with ordinary illuminants; but the error is not of any serious importance in most cases. With temperature radiation, as it is called, the ratio of the visible radiations to the invisible radiations increases with rising temperature, and consequently we get the maximum efficiency at the highest temperature. Since the osmium, tantalum, and tungsten lamps have been developed in consequence of a clear understanding of this principle, it seems probable that we are approaching the limit of efficiency which can be reached in this way.

It seems probable now that the greatest progress is to be made by turning to other methods of producing light and by taking the modest firefly as our model. A step has already been made in this direction. The Moore light, for instance, and the flaming arc are cases where the light is not purely a function of the temperature. By putting suitable salts in a Bunsen flame or an alcohol flame we get an emission of light which varies with the specific substance used and which is not solely a function of the temperature. Addition of sodium salts causes a yellow flame, while we get a red one with strontium salts and a green or blue one with copper salts. This is not a case of cold light in the popular usage of the word; but it belongs under this head theoretically.

The forms of luminescence which are not strictly temperature radiations have been classified by various people under the following heads:

Photoluminescence,
Thermoluminescence,
Pyroluminescence,
Electroluminescence,
Cathodoluminescence,
Anodoluminescence,
Chemiluminescence,
Crystalloluminescence,
Triboluminescence,
Organoluminescence.

When light stimulates a substance to emit light, we call it photoluminescence. If the luminescence lasts an appreciable length of time after the exciting light is cut off, we speak of phosphorescence, whereas we usually speak of fluorescence if the emission of light stops apparently at the same moment that the exciting light is cut off. By thermoluminescence we mean the light that is often emitted by phosphorescent substances when heated gently. Pyroluminescence refers to the light emitted by flames in so far as this is not due to the incandescence of solids. Flame spectra come under this head. Electroluminescence is the term for luminescence produced by the passage of an electric current through a gas. Cathodoluminescence is the luminescence produced by cathode rays when impinging on a solid or liquid, while anodoluminescence is the corresponding luminescence produced by canal rays. Chemiluminescence has been used hitherto solely for those cases where nobody could deny that the light must be due to chemical action. The light emitted during the oxidation of an alkaline pyrogallol solution is a typical instance of chemiluminescence in the narrow sense of the word. Crystalloluminescence is the word used when light is emitted during crystallization from solution, while triboluminescence is used for the light emitted when crystals are crushed. Organoluminescence is the lumin-

escence produced by bacteria, marine organism, luminous worms, flying insects, etc.

When one glances over this imposing list of terms, it is difficult not to be impressed by the wealth of knowledge which these terms seem to connote. A closer examination shows that this classification is based solely on the methods of producing light and not at all on the actual way in which light is produced. We should not be very much impressed by a man who classified fires under the headings: sulphur-match fires; safety-match fires; flint-and-steel fires; friction fires; lightning fires; spontaneous-combustion fires; crossed-wire fires; overheated-flue fires, etc. This classification might be valuable to an insurance man, but it would not tell us much about the theory of fire. It would be more rational to classify as oil, gas, coal, and wood fires, for instance, while a more careful study would show that all ordinary fires came under the general heading of rapid oxidations. Similarly I intend to show that the ten different kinds of luminescence are all cases of chemiluminescence, of luminescence due to chemical action.

When a substance emits light for an appreciable time after it has been exposed to an exciting light, the very existence of a time factor shows that we are dealing with some sort of a chemical reaction, using the term in its broadest sense. Consequently, all cases of phosphorescence are due to chemical reaction. The same reasoning applies to the case of thermoluminescence so-called. Since most cases of phosphorescence can be converted into cases of fluorescence by raising the temperature sufficiently, and since some cases of fluorescence have been converted into phosphorescence by adding gelatine, etc., to the solution, it seems reasonable to conclude that the difference between fluorescence and phosphorescence is a difference in relative reaction velocities. I am inclined to lay stress also on another argument. Since there is no known way of converting monochromatic light of one wave-length directly at ordinary temperatures, by reflection or refraction, into light of any other wave-length, it follows that we must have some chemical action taking place whenever luminescence of any wave-length is produced at ordinary temperatures by the action of light of another wave-length. The only reason for putting in the limitation in regard to ordinary temperatures is to head off the possible case where one would have temperature radiations due to the heating action of the incident light.

In regard to pyroluminescence and electroluminescence I cannot do better than to base my argument on a quotation from Smithells:[6]

"When solids and liquids are heated beyond a certain temperature by an external source of heat, they become luminous, and the intensity of the light emitted increases very rapidly as the temperature is further increased. There is no reason to suppose that gases would behave differently except in degree, for, according to the kinetic molecular theory of matter, light should arise from molecular vibrations occasioned by molecular collisions. It is doubtful, however—whatever may be the case in celestial bodies—whether a gas has ever been brought by artifice into what may be called a state of purely thermal glow. The high transparency of gases to light is correlated to a very low emissivity: iodine vapor, which is an exceptional gas in its absorptive power, does indeed glow when heated in a glass tube, even when the walls are considerably below a red heat; but there is reason to believe that this glow is connected with the dissociation and recombination[7] of the atoms in the iodine molecule.

"Attempts to heat colorless gases, such as nitrogen, to the glowing point have given negative results.

"In almost every case a *flame is glowing gas*, and in view of the facts just recited we must add the qualification, so far as terrestrial conditions are concerned, that *the glow is the accompaniment of chemical change*. It would be possible to refine upon this definition. A 'flame' of pure hydrogen in dustless air is invisible according to Stas, the radiation of short wave-lengths being wholly in the ultra-violet. Again, the glow observed during the decomposition of acetylene in a hot tube may be due wholly to the particles of liberated carbon, and in no degree to anything gaseous. But, speaking generally, the basis of flame is a glowing gas, and the exciting cause chemical action. This description would include ordinary hot flames and also flames of the kind called phosphorescent, which may be quite

[*]Presented at a meeting of the Section of Physics and Chemistry of the Franklin Institute and published in the *Journal* of the Institute.

[1]The Principles of Chemistry, I, 176 (1891).

[2]All transparent substances which transmit light with great ease (that is, which absorb but little light) are but little luminous when heated; so also substances, which absorb but few heat rays, transmit few rays of heat when heated.

[3]There is, however, no doubt but that very heavy, dense vapors or gases under pressure (according to the experiments of Frankland) are luminous when heated, because, as they become denser they approach a liquid or solid state. Thus detonating gas is brightly luminous when exploded under pressure.

[4]This statement is undoubtedly wrong.—W. D. B.

[5]If hydrogen gas be passed through a volatile liquid hydrocarbon—for instance, through benzene (the benzene may be poured directly into a vessel in which hydrogen is generated)—then its vapor burns with the hydrogen and gives a very bright flame, because the resultant particles of carbon (soot) are powerfully ignited. Benzene, or platinum gauze, introduced into a hydrogen flame may be employed for illuminating purposes.

[6]Cf. Thorpe: Dictionary of Applied Chemistry, 2nd Ed. 2, 568 (1912).

[7]See especially Evans: *Astrophys. Jour.* 32, 1 (1910).

cold in the ordinary sense of the word."

The flame spectra of sodium chloride, strontium chloride, and cupric chloride cannot be temperature radiations from solids, because the temperature is the same in the three cases and yet the flames differ tremendously. They cannot be due to heated gases, because we have seen that it is probable that heated gases do not glow if no chemical action takes place. Consequently we conclude that pyroluminescence is a case of luminescence due to chemical action. In line with this is the fact that the carbon bisulphide flame is rich in ultraviolet rays in spite of its relatively low temperature. Since electroluminescence cannot be a temperature radiation from a heated gas, it must also be due to chemical reactions accompanying or following the electrical discharge

In some cases, at any rate, the luminescence due to cathode rays or canal rays is similar to that produced by ultra-violet light or to that of flame spectra. For these cases we must therefore conclude that the cathode rays and canal rays produce light as a result of chemical action. Until there is some definite evidence showing fundamental differences between one case of cathodoluminescence and another we must postulate that all cases of cathodoluminescence or of adonoluminescence are cases of chemiluminescence. Under the circumstances it seems safe to assume that crystalloluminescence and triboluminescence are cases of chemiluminescence; and we know that the organoluminescence, so-called, of the firefly is due to chemical action. We therefore generalize that all forms of luminescence, with the possible exception of temperature radiations, are due to chemical action, using the term in its broadest sense.

The generalization that luminescence is always due to chemical reaction is not new. Pringsheim[2] made out a very strong case twenty years ago for the view that no gas emits light except as a result of chemical action. Armstrong[3] put forward the view, ten years ago, that luminosity and line spectra are the expression—visible signs—of the changes attending the formation of molecules from their atoms, or, speaking generally, that they are consequences of chemical changes. The difficulty is that the generalization has not been taken seriously by anybody, not even by Pringsheim himself. People speak of the carbon spectrum, the cyanogen spectrum, and the carbon monoxide spectrum, for instance, instead of speaking of the spectrum due to this, that, or the other reaction. There has been very little progress in the twenty years since Pringsheim's paper appeared.[10] This is not very surprising. People studied electromotive forces for a great many years before it became clear to them that they ought to speak of the electromotive force of a reaction[11] instead of the electromotive force of certain substances.

Having decided that luminescence is always due to a chemical reaction, we are confronted with two problems, as to the particular reactions in any given case, and as to what reactions give out light and the conditions under which this takes place. I shall consider these two problems separately.

Wiedemann and Schmidt[12] were unable to determine whether the emission of light was due to the decomposition of any given substance or to the reverse reaction. Wilkinson[13] showed what reactions emitted light when cathode rays acted on certain salts by guessing at the reactions and then duplicating them chemically. Under the influence of the cathode rays, mercury bromide gives an orange glow, cuprous iodide a violet-red one, sodium chloride a bluish-white one, and potassium iodide a green one. He obtained the same type of light by letting the halogen react with the metal under suitable conditions. With halide salts there are not many reactions possible; but the problem becomes more complex when we come to sulphates. The light may be due, for instance, to the reaction between metal and oxygen, the conversion to sulphate not emitting light. The essential reaction may be conversion of oxide to sulphate, or it may be the reaction between metal and sulphate radical. At present the only way to distinguish between these hypotheses is to test each experimentally. This was done by Wilkinson in three cases, and the results are given in Table I.

TABLE I.

Reaction	Light
PbSO₄ and cathode rays	blue
Pb +O=PbO	none
PbO +SO₃=PbSO₄	white
Pb +(NH₄)₂S₂O₈=PbSO₄ +(NH₄)₂SO₄	blue
ZnSO₄ and cathode rays	bluish-white
Zn +O=ZnO	green
ZnO +SO₃=ZnSO₄	green
Zn +(NH₄)₂S₂O₈=ZnSO₄ +(NH₄)₂SO₄	bluish-white

[1] Wied. Ann. 45, 429 (1892).
[2] Proc. Roy. Soc. 70, 99 (1902).
[3] Cf. however, J. J. Thomson: Chem. News. 103, 265 (1911).
[10] Haber: Zeit. Elektrochemie, 7, 443 (1901).
[11] Wied. Ann. 56, 243 (1895).
[12] Jour. Phys. Chem. 13, 691 (1909).

CdSO₄ +cathode rays	yellow
Cd +O=CdO	yellow
CdO +SO₃=CdSO₄	yellow
Cd +(HN₃)₂S₂O₈=CdSO₄ +(NH₄)₂SO₄	white

From this table it is clear that the cathode rays break up lead sulphate and zinc sulphate into metal and the sulphate radical, and that the reverse reaction emits the light. In the case of lead sulphate this conclusion was confirmed by letting the cathode rays act for a long time, keeping the pump going all the time. The lead salt blackened, and a microchemical analysis showed the blackening to be due to metallic lead. So far as the color test goes, all we can say about cadmium sulphate is that the essential reaction is not that between the metal and the sulphate radical. Of the two other possible reactions we naturally select the one between cadmium oxide and sulphur trioxide, because it must take place before the oxide can be decomposed by the cathode rays. Wilkinson found that cadmium sulphate turns brown when exposed for a long time to the cathode rays while the pump is kept running. This brown product was identified microchemically as cadmium oxide.

So far everything has been satisfactory; but now we come to a difficulty. Wilkinson[14] found that a bluish light was emitted when sodium burned slowly in chlorine or oxygen, while the yellow flame, usually considered characteristic of sodium, was obtained when the combustion took place rapidly. There are thus two reactions which must be separated so far as possible. Both the bluish and the yellow luminescence are evidently due to the sodium, because they are modified but slightly by the nature of the acid radical, though Wilkinson noticed a trace of green in the flame when sodium burned in iodine. We shall come back to this point later. The best method of attacking the problem of the reactions giving rise to the two spectra is to find out under what conditions these two spectra are obtained.

When canal rays act on sodium chloride we get the yellow luminescence[15], while cathode rays cause the bluish luminescence. Lenard[16] has shown that fused salts of the alkalies are luminescent, the sodium salts emitting a sky-blue light. This being so, one would expect to get a similar spectrum developed somewhere in the Bunsen flame, and this has actually been observed by Lenard in that portion of the flame separating the reducing zone from the oxidizing zone. Lenard also showed that the yellow flame is electrically neutral, while the bluish flame contains ions of some sort. As far as I can make out, the bluish luminescence is the same as the "continuous spectrum" of Kirchhoff and Bunsen.[17]

Bandrowski[18] has made experiments on the emission of light when sodium chloride is precipitated from aqueous solution by alcohol or by hydrochloric acid. When the precipitation takes place under suitable conditions of concentration and temperature, a bluish-white light is emitted. This is so like the bluish luminescence of sodium chloride that one is tempted to look upon the two as identical. Owing to the faintness of the crystalloluminescence, it is very difficult to be sure of this fact; but a confirmation, such as it is, may be found in the fact that Bandrowski obtained a greener light when potassium chloride was substituted for sodium chloride. This change is in the right direction, because Lenard found that fused potassium salts emit a green light and that a green light can be obtained with potassium salts in the Bunsen flame.

This point has been taken up recently in my laboratory by Mr. E. F. Farnau,[19] who has confirmed and extended the experiments of Bandrowski:

"After half an hour's wait in the dark room until the eyes became sufficiently sensitive, 50 cubic centimeters of saturated solutions of each of the salts, sodium and potassium chloride, bromide, and iodide were shaken with 50 cubic centimeters of alcohol in a 100 cubic centimeter graduate, and the glow appearing during precipitation was observed. In similar manner concentrated hydrochloric acid was employed as precipitant of the chlorides of sodium and potassium. The results as tabulated (in Table II) indicate the identity of the luminescence, whether produced by cathode rays, chemical combination, or precipitation."

TABLE II.
Color of Luminescence.

Salt.	Cathode ray	Chemical reaction.	Precipitation.
NaCl	bluish-white	blue	bluish-white
NaBr	bluish-white	blue-white	bluish-white
NaI	greenish-white	white (greenish?)	greenish-white
KCl	bluish-white	blue	bluish-white
KBr	blue	blue	blue
KI	green	greenish-white	green

In the case of the fused salt and in the case of the precipitation of the dissolved salt, only one reaction seems possible. We are dealing with the change from the

[14] Jour. Phys. Chem., 13, 703 (1909).
[15] Arnold: Wied. Ann., 61, 326 (1897).
[16] Drude's Ann., 17, 199 (1905).
[17] Kayser: Handbuch der Spectroscopie, 6, 34 (1912).
[18] Zeit. Phys. Chem., 15, 325 (1894).
[19] Eighth Internat. Congress Applied Chemistry, 20, 127 (1912).

ion to the undissociated substance. There is, of course, no reason why the cathode rays should not disintegrate sodium chloride into sodium as ion and chlorine as ion. It has been proved that lead sulphate is decomposed into lead and the acid radical, and it is more in line with our usual way of looking at things to postulate SO₄ inches as ion. The more serious difficulty comes when we consider the slow combustion of sodium in chlorine or oxygen. In order to bring these results in line with the others, we must assume that the reaction between sodium and chlorine or oxygen takes place in at least two stages, sodium as ion being one intermediate product. This is not really a far-fetched assumption. We make a similar one in regard to reactions of metals or gases in aqueous solution. It is a necessary assumption if we are going to consider the formation and decomposition of sodium chloride as a reversible process.

If the change from sodium as ion to the undissociated compound is the reaction which emits the bluish luminescence, we apparently have the change from electrically neutral sodium vapor to sodium as ion as the reaction causing the yellow light which we ordinarily associate with sodium. This would be a legitimate conclusion if we could be certain that there was only one reaction to be considered. This is not the case. Lenard[20] has shown that there are several sodium spectra, and the experiments of Wood and Galt[21] on the fluorescence of sodium vapor lead to the same conclusions. A good deal of work must be done before we can state specifically the reaction corresponding to each spectrum or spectrum series. On the other hand, there seems to be no danger of there not being enough possible reactions. J. J. Thomson[22] has recently shown that we have at least nine different substances when a current passes through oxygen gas: neutral molecular oxygen, O₂; neutral atomic oxygen, O; atomic oxygen with one positive charge, O˙; atomic oxygen with two positive charges, O˙˙; atomic oxygen with one negative charge, O'; molecular oxygen with one positive charge O'₂; ozone with one positive charge, O'₃; polymerized oxygen with one positive charge, O'₄; free negative corpuscles.

When sodium burns slowly in chlorine or oxygen, the change from sodium as ion to the undissociated compound is the only reaction taking place with sufficient rapidity to cause the emission of light. When the combustion is more rapid, we get the emission of yellow light which corresponds to the second, as yet unformulated, reaction. The intensity of this light is relatively so high that it ordinarily masks the continuous spectrum,[23] having a maximum in the blue. If hydrochloric acid be passed into a sodium flame, the yellow color disappears and we get the continuous spectrum. A mixture of NaCl and NH₄Cl gives very little yellow to an alcohol flame.

The work of Pringsheim[24] brings out clearly the relation between the flame spectra of sodium salts and the combustion spectra. Pringsheim showed that the illuminating gas in the Bunsen flame reduced the sodium salts, and that the yellow light was due to the oxidation. Out in the oxidizing zone of the Bunsen flame we have rapid combustion, and consequently we get the yellow light, just as we do when sodium burns rapidly in chlorine or oxygen. At the surface separating the reducing zone and the oxidizing zone we have the lowest rate of oxidation, and consequently we should expect to find, what Lenard actually found, the same luminescence which is obtained when sodium burns slowly in chlorine or oxygen. We are not limited now to the chemical reactions which were known twenty years ago, and we do not have to postulate a reaction between sodium and another chemical element in order to account for the yellow light. The value of Pringsheim's work consists in his conception that the reaction causes the light.

Trautz[25] considers all cases of luminescence during crystallization (crystalloluminescence) as cases of triboluminescence or luminescence produced by crushing crystals. In view of what we have seen of the relation between crystalloluminescence, luminescence due to cathode rays, luminescence due to combustion, etc., it is clear that the hypothesis of Trautz cannot be maintained in its present form. I see no objection to wording the hypothesis in another way. I should prefer to say that, in some cases, triboluminescence is the same as crystalloluminescence. When two crystals are rubbed together, one will become electrified positively and the other negatively. One way for this electrification to take place would be by a dissociation, sodium as ion going to one crystal and chlorine as ion to the other. A recombination, or an oxidation of the sodium, would then cause an emission of light which should be the same in quality as the light emitted under some other conditions.

[20] Drude's Ann., 11, 636 (1903).
[21] Astrophys. Jour., 33, 72 (1911).
[22] Chem. News, 103, 265 (1911).
[23] Lenard: Drude's Ann., 17, 208 (1905).
[24] Wied. Ann., 45, 428 (1892).
    Vol. CLXXV, No. 1046—9.
[25] Zeit. Elektrochemie, 11, 307 (1905); Zeit. Phys. Chem., 53, 12 (1905).

There is no difficulty about confirming this if we stick to sodium salts, because most triboluminescence is apparently bluish-white. Owing to the relatively faint light emitted as triboluminescence, it is very difficult to decide whether potassium iodide, for instance, gives a green light or the mercury halides an orange light. We hope to get definite evidence on this before long; but, for the present, a definite statement is not possible. In the case of sugar and substances of that type, luminescence in the Bunsen flame could not be the same as triboluminescence; but I should expect the triboluminescence to coincide in quality with the luminescence produced either by cathode or by the canal rays, as the case might be.

Having shown how it is possible, in many cases, to discover what specific reaction is emitting light, we can now take up the second question and can ask what reactions give out light and under what conditions. The answer to this is very simple. All reactions tend to emit light, and all reactions do emit light when the reaction velocity is sufficiently high, though the absolute speeds necessary in any two cases may be very different. This is merely a further extension of conclusions previously reached by others. Trautz[26] pointed out that an extraordinary number of chemical reactions are accompanied by emission of light, and that the intensity of light increases with increasing reaction velocity. It is easy to show that some reactions emit no visible light under certain conditions but do emit light when the conditions are more favorable. Wilkinson[27] found that "bismuth, tin, zinc, and cadmium all give negative results when heated in a current of oxygen. However, when cadmium is heated with a blast lamp until it volatilizes, it combines with oxygen and burns with a deep-yellow flame to the reddish-brown oxide. Zinc, heated in the blast to boiling, burns with a green flame." Cases of this sort could be duplicated indefinitely. A very satisfactory experiment is to mix powdered calcium carbonate with red fire. It is very easy to arrange the proportions so that the red fire burns completely without showing any red.

Bandrowski[28] says: "I first studied the crystallization of sodium chloride, potassium chloride, potassium bromide, potassium sulphate, and potassium nitrate from aqueous solutions. I caused the crystallization to take place under all sorts of conditions: at different temperatures; by evaporating on the water bath, on the sand bath, or over a free flame; by sudden cooling (passing the supersaturated solution through a spiral tube which was kept very cold). In no case was I able to detect any emission of light.

"I accounted for this negative result by assuming that, under these conditions, the ions combined so slowly and over so large a space that the emission of light was too faint to be detected by the eye, more especially since a very intense light was scarcely to be expected even under the most favorable conditions. It became necessary, therefore, to do the experiments under such conditions that the forcing back of the dissociation would be practically instantaneous. It seemed to me that this could be done by adding a liquid which would be miscible in all proportions with water but which would precipitate these salts. Alcohol and aqueous hydrochloric acid are such liquids.

"The experiment confirmed my assumption, and I was able to obtain light effects which were fairly strong with some of the salts, provided the concentrations of the two liquids were adjusted carefully."

In the case of the so-called temperature radiation from solids, the quality of the light changes with rising temperature. On the other hand, the change of the intensity with the temperature is described by a general formula applicable to all wave-lengths. If we omit this case, as before, we seem to be justified in concluding that a fairly definite spectrum corresponds to each definite reaction, and that any marked change in a spectrum indicates the occurrence of another reaction.

It is well known that the phosphorescent sulphides of zinc, calcium, strontium, and barium do not phosphoresce unless they contain traces of copper, bismuth, manganese, etc., and it is also well known that the color of the light emitted by the phosphorescing sulphides seems to be determined by the nature and amount of the salts of copper, bismuth, manganese, etc., Wilkinson[29] found that the sulphates of sodium, lithium, potassium, and zinc increase the phosphorescence of cadmium sulphate when exposed to cathode rays, but apparently without changing the quality of the emitted light to any appreciable extent. I interpret this to mean that these salts act as catalytic agents, accelerating the rate of reaction between cadmium oxide and sulphur trioxide, and thereby causing the emission of more light. In the case of the phosphorescent sulphides, the reaction which emits

[26]Trautz, Zeit. Phys. Chem., 53, 1 (1905); Zeit. Elektrochemie, 14, 453 (1908).
[27]Jour. Phys. Chem., 13, 704 (1909).
[28]Zeit. Phys. Chem., 15, 324 (1894).
[29]Jour. Phys. Chem., 13, 719 (1909).

light must be a reaction of the salts of copper, bismuth, manganese, etc., while the sulphides of zinc, calcium, strontium, or barium act as a medium to permit dissociation, just as water does with salts.

Welding Nickel

Certain metals, and among them nickel, have the property of dissolving, when molten, considerable quantities of gases, especially of hydrogen. Such gases are expelled when the metal solidifies. This causes any welded joint that may be attempted, to be porous and to break open on cooling.

Fig. 1.—Welding up small cracks and pores in sheet nickel.

In order to obviate this porosity of the weld, the operation is best carried out at a temperature below that at which this absorption of gases begins.

Nickel, like iron and most other metals, can be welded; in other words, it can be "kneaded" at a tempera-
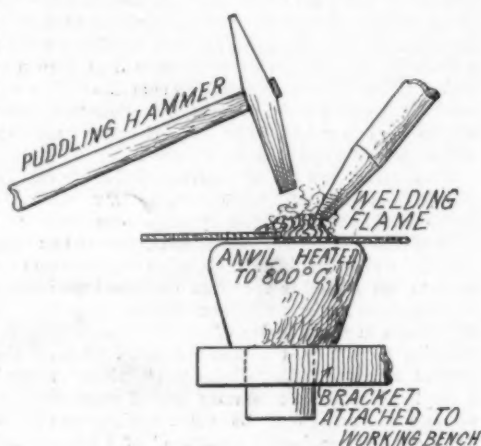

Fig. 2.—Welding sheet nickel under the hammer.

ture sufficiently high to cause a softening of the metal, without actually fusing it.

But hitherto it was impossible to remedy in any way the porous joints which always occur among the product. Pieces with such defect had to be simply scrapped.

A remedy has been found in an application of the autogenous welding process. The porous spot is first
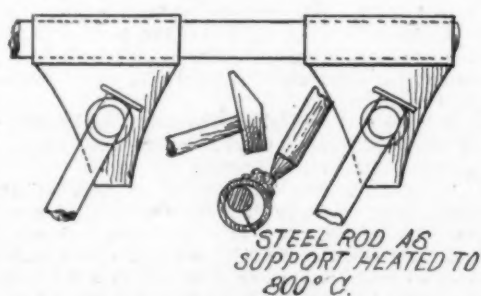

Fig. 3.—Manufacture of seamless nickel tubing by autogenous welding.

worked over with a borer or a file until it is quite clean, and a piece of nickel wire is then thrust into the opening, after first heating up the part to the requisite temperature.
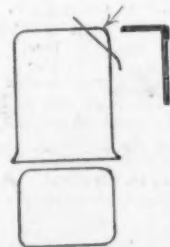
The heat is then kept up by playing on the spot with

Fig. 4.—Repairing the corners of pressed nickelware.

a blast flame, and a nickel wire is driven into the pore by hammer blows. The anvil on which this work is carried out should be heated to a dark red heat. Fig. 2 shows the welding of simple nickel objects, such as two pieces of sheet nickel. The anvil may be heated upon a coal fire or by means of a blast flame. The two pieces of sheet nickel to be joined are first cleaned at the junction, and are then heated with a blast flame and hammered with small hammers such as are used in puddling iron. In this way a good weld is obtained.

In preparing seamless nickel pipe, as shown in Fig. 3, a similar method is employed, and in fact the method is adaptable to all kinds of work.

Fig. 4 shows how the edges of drawn nickel vessels can be repaired by welding in new corner pieces.

The following precautions must be observed: 1. The hammers used must be small, weighing about a pound, and provided with long handles, and the work must rest upon an iron support at a temperature of about 700 to 800 deg. Cent.

2. The metal surfaces to be welded must be absolutely free from fat and from grease and oil, and must be polished perfectly by scraping them or in any other suitable manner.

3. The hammering must be done at a white heat of the nickel with the support at a temperature of not less than 700 deg. Cent.

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